# RECORDS

OF

# THE GEOLOGICAL SURVEY OF INDIA.

## VOLUME LXVII.

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1934

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# RECORDS

OF

# THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1933. [April

## GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1932. BY L. L. FERMOR, O.B.E., D.Sc., A.R.S.M., F.G.S., F.A.S.B., M.I.M.M., *Director, Geological Survey of India.*

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## DISPOSITION LIST.

DURING the period under report the officers of the Department were employed as follows:—

*Superintendents.*

DR. G. DE P. COTTER . Remained at headquarters till the 11th May, 1932. Granted leave on average pay for 1 month and 16 days combined with leave on half average pay for 14 months, preparatory to retirement, from the 12th May, 1932.

DR. J. COGGIN BROWN Placed in charge of the Burma Circle till the 12th April, 1932. Granted leave on average pay for 16 days combined with leave on half average pay for 26 months and 10 days, preparatory to retirement, from the 13th April, 1932.

MR. H. C. JONES Except for a brief visit to the iron-ore mines of Singhbhum in January, remained at headquarters till the 14th April, 1932. Granted leave on average pay for 15 days combined with leave on half average pay for 13 months and 26 days, preparatory to retirement, from the 15th April, 1932.

*Superintendents*—contd.

DR. A. M. HERON . Remained at headquarters in charge of the Northern Circle till the 28th April, 1932, and officiated as Director from the 29th April to the 15th November, 1932. Placed in charge of the Northern Circle and left for Rajputana on the 17th December, 1932.

DR. C. S. FOX . . Returned from the field on the 21st April, 1932. Placed in charge of the Southern Circle and left for Assam on the 19th November, 1932.

MR. E. L. G. CLEGG . Placed in charge of office as Assistant Director till the 28th April, 1932. Placed in charge of the Burma Circle and left for Rangoon on the 29th April, 1932. Appointed to officiate as Superintendent from the 2nd May to the 24th June, 1932, and confirmed in that grade from the 25th June, 1932.

*Assistant Superintendents.*

MR. H. CROOKSHANK . Returned from leave and resumed duty on the 21st September, 1932. Appointed to officiate as Superintendent from the 21st September to the 15th November, 1932, and placed in charge of the Northern Circle during that period. Attached to the Southern Circle and left for the Bastar State, Central Provinces on the 16th November, 1932.

MR. G. V. HOBSON . On leave preparatory to retirement.

RAO BAHADUR M. VINAYAK RAO. On leave preparatory to retirement.

*Assistant Superintendents*—contd.

MR. E. J. BRADSHAW . Returned from leave and resumed duty on the afternoon of the 20th August, 1932. Attached to the Southern Circle and left for Assam on the 4th December, 1932.

MR A. L. COULSON . Returned from the field on the 28th March, 1932. Placed in charge of office as Assistant Director from the 29th April to the 21st June, 1932, and again from the 21st September, 1932. Appointed to officiate as Superintendent from the 12th May to the 20th September, 1932.

MR. D. N. WADIA . Remained at headquarters as Palæontologist.

DR. J. A. DUNN . . Returned from leave and resumed duty on the 10th October, 1932. Attached to the Southern Circle and left for Dhalbhum, Bihar and Orissa, on the 16th November, 1932.

MR. C. T. BARBER . Continued as Resident Geologist at Yenangyaung and Official Member of the Yenangyaung Advisory Board. Placed in charge of the Burma Circle from the 13th April to the 1st May, 1932, in addition to his other duties.

MR. E. R. GEE . . Returned from the field on the 12th June, 1932. Placed in charge of office as Assistant Director from the 22nd June to the 20th September, 1932. Attached to the Northern Circle and left for the Salt Range, Punjab, on the 4th November, 1932.

*Assistant Superintendents*—contd.

| | |
|---|---|
| MR. W. D. WEST . | Remained at Headquarters as Curator of the Geological Museum and Laboratory. |
| MR. A. K. BANERJI . | Remained at headquarters. Granted combined leave for 8 months and 16 days, preparatory to retirement, from the 16th February, 1932. Retired from service from the 1st November, 1932. |
| DR. M. S. KRISHNAN . | Returned from the field on the 24th April, 1932. Attached to the Southern Circle and left for Singhbhum on the 16th November, 1932. |
| MR. P. LEICESTER . | Remained at Rangoon. Granted leave on half average pay for 14 months and 10 days, preparatory to retirement, from the 27th February, 1932. |
| DR. S. K. CHATTERJEE. | Remained at headquarters. Granted leave on half average pay for 18 months and 14 days, preparatory to retirement, from the 16th February, 1932. |
| MR. J. B. AUDEN . | Left for the field on the 13th January, 1932 and returned to headquarters on the 15th July, 1932. Attached to the Northern Circle for work in the Himalayas and left for the field on the 19th December, 1932. |
| MR. V. P. SONDHI | Returned from the field on the 11th June, 1932. Left for recess in Calcutta on the 25th June, 1932. Attached to the Burma Circle to continue his work in the Southern Shan States and left for Rangoon on the 6th November, 1932. |

*Assistant Superintendents*—concld.

| | |
|---|---|
| MR. B. B. GUPTA . | Remained at headquarters. Granted leave on average pay for 4 months combined with leave on half average pay for 16 months and 15 days, preparatory to retirement, from the 17th February, 1932. |

*Extra Assistant Superintendents.*

| | |
|---|---|
| DR. H. L. CHHIBBER . | Remained at Rangoon. Granted leave on half average pay for 14 months from the 2nd January, 1932. |
| DR. P. K. GHOSH | Returned from the field on the 30th April, 1932. Attached to the Northern and Southern Circles for work in Bombay and Madras, respectively and left for the field in Bombay on the 18th November, 1932. |
| DR. M. R. SAHNI | Returned from the field to Rangoon on the 24th May, 1932. Left for recess in Calcutta on the 31st May, 1932. Attached to the Burma Circle and left for Rangoon to continue the survey of the Northern Shan States on the 25th November, 1932. |
| MR. D. BHATTACHARJI . | Left for the field on the 11th January, 1932 and returned to headquarters on the 5th April, 1932. Granted leave on average pay for 3 months and 15 days from the 9th May, 1932. Returned from leave and resumed duty on the 25th August, 1932. Attached to the Southern Circle to continue his work in the Bhandara and Nagpur districts and left for the field on the 11th November, 1932. |

*Extra Assistant Superintendent*—contd.

| | |
|---|---|
| MR. B. C. GUPTA . | Left for the field on the 29th January, 1932 and returned to headquarters on the 1st May, 1932. Granted leave on average pay for 13 days. Returned from leave and resumed duty on the 31st October, 1932. Attached to the Northern Circle for work in Bombay and Central India and left for the field on the 10th November, 1932. |
| MR. H. M. LAHIRI . | Returned from the field on the 4th May, 1932. Granted leave on average pay for 2 months and 12 days from the 20th June, 1932. Returned from leave and resumed duty on the 1st September, 1932. Attached to the Northern Circle for work in the Punjab and left for the field on 10th November, 1932. |
| DR. L. A. NARAYANA IYER. | Returned from the field to Rangoon on the 25th April, 1932. Left for recess in Calcutta on the 26th April, 1932. Attached to the Burma Circle for work in the Mogok Stone Tract and left for Rangoon on the 13th November, 1932. |
| MR. P. N. MUKERJEE . | Left for the field on the 9th January, 1932 and returned to headquarters on the 28th March, 1932. Attached to the Northern Circle for work in Bombay and Central India and left for the field on the 10th November, 1932. |
| MR. A. K. DEY . . | Returned from leave and resumed duty on the 10th August, 1932. Attached to the Southern Circle and left for Dhalbhum on the 19th November, 1932. |

*Chemist.*

DR. W. A. K. CHRISTIE Retired from service from the 10th October, 1932.

*Artist.*

MR. K. F. WATKINSON Remained at headquarters. Granted leave on average pay for 11 days combined with leave on half average pay for 27 months and 6 days, preparatory to retirement from the 1st March, 1932.

*Assistant Curator.*

P. C. ROY . . At headquarters. Granted leave on average pay for 15 days from the 6th January, 1932. Returned from leave on the 21st January, 1932. Granted leave on average pay from the 5th to the 23rd December, 1932, with permission to affix the Christmas holidays.

*Field Collectors.*

V. K. N. AYENGAR . At headquarters.

AUSTIN M. N. GHOSH. Officiated as Extra Assistant Superintendent from the 11th January, 1932. Attached to the Northern Circle for work in the Salt Range, Punjab, and to collect fossils there. Left for the field on the 11th January, 1932, and returned to headquarters on the 17th May, 1932. Attached to the Southern Circle for work with Dr. C. A. Matley to collect dinosaurian fossils in the Central Provinces and left for the field on the 26th November, 1932.

*Assistant Chemist.*

MAHADEO RAM . . At headquarters. Granted leave on average pay for 1 month and 29 days from the 7th March, 1932. Returned from leave on the 6th May, 1932, and remained at headquarters during the rest of the period.

*Museum Assistants.*

D. GUPTA . . . At headquarters.

A. B. DUTTA . . At headquarters.

*Temporary Museum Assistants.*

K. P. HARAN . . At headquarters. Services dispensed with from the 1st March, 1932, due to retrenchment.

M. S. VENKATRAM . At headquarters.

2. The cadre of the Department consisted of 3 Superintendents and 10 Assistant Superintendents.

## ADMINISTRATIVE CHANGES.

Promotions and appointments.

3. Dr. L. L. Fermor continued to officiate as Director up to the 28th April, 1932, *vice* Sir Edwin Pascoe on leave, and from the 29th April, 1932, he availed himself of combined leave for six months and seventeen days. He was confirmed in the appointment of Director with effect from the 25th June, 1932.

Dr. A. M. Heron officiated as Director from the 29th April to the 24th June, 1932, *vice* Sir Edwin H. Pascoe on leave, and again

from the 25th June to the 15th November, 1932, *vice* Dr. L. L. Fermor on leave.

Mr. E. L. G. Clegg officiated as Superintendent from the 2nd May to the 24th June, 1932, *vice* Dr. A. M. Heron officiating as Director, and was confirmed in the appointment of Superintendent with effect from the 25th June, 1932.

Mr. H. Crookshank officiated as Superintendent from the 21st September to the 15th November, 1932, *vice* Dr. A. M. Heron officiating as Director.

Mr. A. L. Coulson officiated as Superintendent from the 12th May to the 24th June, 1932, *vice* Dr. L. L. Fermor on leave, and again from the 25th June to the 20th September, 1932, *vice* Dr. A. M. Heron officiating as Director.

Mr. E. L. G. Clegg continued to act as Assistant Director till the 28th April, 1932, when he was relieved by Mr. A. L. Coulson. From the 22nd June to the 20th September, 1932, Mr. E. R. Gee acted as Assistant Director, and thereafter Mr. A. L. Coulson.

Mr. A. M. N. Ghosh officiated as Extra Assistant Superintendent from the 11th January, 1932 to the 9th August, 1932, *vice* Mr. A. K. Dey on leave, and from the 10th August, 1933, *vice* Dr. H. L. Chhibber on leave.

Retirement.

4. Sir Edwin H. Pascoe, Kt., Director, retired from the service with effect from the 25th June, 1932.

Mr. A. K. Banerji, Assistant Superintendent, retired from the service with effect from the 1st November, 1932

Dr. W. A. K. Christie, Chemist, retired from the service with effect from the 10th October, 1932.

Leave.

5. Dr. L. L. Fermor was granted combined leave out of India for six months and seventeen days with effect from the 29th April, 1932.

Dr. G. de P. Cotter was granted combined leave out of India for one year, three months and sixteen days, preparatory to retirement, with effect from the 12th May, 1932.

Dr. J. Coggin Brown was granted combined leave out of India for two years, two months and twenty-six days, preparatory to retirement, with effect from the 13th April, 1932.

Mr. H. C. Jones was granted combined leave out of India for one year, two months and eleven days, preparatory to retirement, with effect from the 15th April, 1932.

Mr. E. J. Bradshaw was granted an extension of combined leave for five months and twenty-three days with effect from the 26th February, 1932.

Mr. A. K. Banerji was granted leave on half average pay for eight months and sixteen days, preparatory to retirement, with effect from the 16th February, 1932.

Mr. P. Leicester was granted leave on half average pay for one year, two months and ten days, preparatory to retirement, with effect from the 27th February, 1932.

Dr. S. K. Chatterjee was granted leave on half average pay for one year, six months and fourteen days, preparatory to retirement, with effect from the 16th February, 1932.

Mr. B. B. Gupta was granted combined leave for one year, eight months and fifteen days, preparatory to retirement, with effect from the 17th February, 1932.

Dr. H. L. Chhibber was granted leave out of India on half average pay for one year and two months with effect from the 2nd January, 1932.

Mr. D. Bhattacharji was granted leave on average pay for three months and fifteen days with effect from the 9th May, 1932.

Mr. B. C. Gupta was granted leave on average pay for thirteen days with effect from the 15th October, 1932.

Mr. H. M. Lahiri was granted leave on average pay for two months and twelve days with effect from the 20th June, 1932.

Mr. K. F. Watkinson was granted combined leave out of India for two years, three months and twenty days, preparatory to retirement with effect from the 1st March, 1932.

## LECTURESHIPS.

6. Mr. W. D. West continued to act as a part-time Professor of Geology at the Presidency College, Calcutta.

Mr. E. L. G. Clegg continued to act as part-time Lecturer on Geology at the Bengal Engineering College, Sibpur, till the 28th April, 1932; thereafter Mr. A. L. Coulson filled this post up to the 31st October, 1932.

## POPULAR LECTURE.

7. A popular lecture on 'Glaciers' was delivered in the Indian Museum by Mr. J. B. Auden during the year.

## PUBLICATIONS.

8. The following publications were issued during the year under report :—

1. Records, Vol. LXV, Part 4.
2. Records, Vol. LXVI, Part 1.
3. Records, Vol. LXVI, Part 2.
4. Records, Vol. LXVI, Part 3.
5. Memoirs, Vol. LXI.
6. Palæontologia Indica, New Series, Vol. XVIII.
7. Palæontologia Indica, New Series, Vol. XX, Memoir No 1.
8. Palæontologia Indica, New Series, Vol. XX, Memoir No. 2.
9. Palæontologia Indica, New Series, Vol. XX, Memoir No. 3.
10. Index to Memoirs, Vols. I-LIV.

The issue of Records, Volume LXVI, Parts 2 and 3, for which print-off orders were given during the year has been severely delayed on account of the Press running short of the paper upon which this publication is printed.

## LIBRARY.

9. The additions to the library amounted to 3,260 volumes of which 1,099 were acquired by purchase and 2,161 by presentation and exchange.

## DRAWING OFFICE.

10. The Artist, Mr. K. F. Watkinson, was in charge of the Drawing Office till the end of February, 1932, and proceeded on leave preparatory to retirement on the 1st March. As a measure of economy the post was then made a non-gazetted one and filled by Mr. S. Ray, who held charge of the Drawing Office for the remainder of the year. The Drawing Office staff was reduced from 10 to 7 as a measure of retrenchment.

11. During the year, 99 halftone and line blocks were prepared for plates of the Records, Memoirs and Palæontologia Indica, and 65 plates were printed off. 43 drawings and 93 line blocks for text figures, were also prepared.

Publications.

The number of geologically coloured originals received from officers totalled 60, while 2,343 topographical sheets were received

from the Director, Map Publication, Survey of India, and 530 were issued for departmental use.

**Photographic Section.**

12. This department was fully occupied with copying, developing and printing work for publications and reports. The number of negatives received into stock totalled 448, while 891 photographic prints were made. In addition, 72 lantern slides were prepared.

## MUSEUM AND LABORATORY.

**Staff.**

13. Mr. W. D. West continued as the Curator of the Geological Museum and Laboratory throughout the year. Babu Purna Chandra Roy, Assistant Curator, was on leave from the 5th December until the end of the year. Babus Dasarathi Gupta and Anil Bhusan Dutt continued as Museum Assistants. M. R. Ry. M. S. Venkatram acted as a temporary Museum Assistant throughout the year, while M. R. Ry. K. P. Haran worked in the same capacity until the 28th February, when his temporary post was abolished as a measure of retrenchment. Mahadeo Ram, Assistant Chemist, was on leave from the 7th March to the 5th May.

**Chemist.**

14. Dr. W. A. K. Christie was on leave until the 9th October and retired with effect from the following day. On the recommendation of the Retrenchment Advisory Committee, the Government of India decided to abolish the post of Chemist upon the retirement of Dr. Christie.

**Determinative work and analyses.**

15. The number of specimens referred to the Curator during the year for examination and report was 385, of which analyses, assays and other special determinations were made of 44. The corresponding figures for 1931 were 637 and 37 respectively. Chemical work included analyses of coal, limestone, lead, silver, manganese, iron pyrites, graphite, brine, dolerite, clay, and rock specimens submitted by officers of the Department.

**Donations to Colleges, etc.**

16. During the year under review collections of Indian rocks and minerals were presented to the following institutions :—

1. St. Andrew's Colonial Home, Kalimpong.
2. The Intermediate College of Science, Bangalore.

3. The Hailey College of Commerce, Lahore.
4. The Archæological Department.
5. The University College of Science, Calcutta.
6. The Mrs. Keoki Monroe Perin Memorial High School, Jamshedpur.

In addition the following specific presentations were made :—

1. Bauxite, to Prof. F. J. Loewenson-Lessing, Leningrad.
2. Desert sands, to G. R. McCarthy, Esq., University of North Carolina.
3. Desert sandstone, to Prof. B. Sahni, University of Lucknow.
4. Sodalite rock, to Mr. S. G. Gordon, Academy of Natural Sciences, Philadelphia.
5. Charnockite, to Prof. H. Ries, Cornell University, Ithaca, New York.
6. Talchir boulder, to Prof. Buxtorf, University of Basel.
7. Brine, to Prof. L. G. M. Baas-Becking, University of Leiden, Holland.
8. Fragments of Shalka and Manegaon meteorites, to Prof. A. Lacroix, Paris.
9. Sillimanite and glass sand, to Prof. H. E. Watson, Indian Institute of Science, Bangalore.
10. Allanite, columbite, monazite sand, zircon sand and samarskite, to H. S. Spence, Esq., Department of Mines, Canada.

17. In addition to the large number of specimens collected by the officers of the Department, the following important Indian specimens were received and incorporated in the collections of the Geological Survey of India :—

1. Molybdenite, Tavoy-Kyaukmedaung road, Burma; presented by Mr. S. H. Harman.
2. Pyrolusite, Keonjhar State; presented by Dr. E. Spencer.
3. Barytes, Kurnool and Cuddapah districts, Madras; presented by M. R. Ry. B. P. Sesha Reddy, M.L.C.
4. Barytes, Garpos, B. N. Ry.; presented by Messrs. Young & Co.
5. Fossil wood, Dishergarh seam, Parbelia Colliery; presented by the Bengal Coal Co., Ltd.

The following foreign specimens were added to the collection of the Department by exchange with the Department of Mines, Ottawa :—

1. Uraninite, Ontario.
2. Euxenite, West Portland township, Quebec.
3. Allanite, Hybla, Ontario.
4. Ellsworthite with cyrtolite in calcite, Hybla, Ontario.
5. Cyrtolite with ellsworthite, Hybla, Ontario.

**Meteorite.**

18. On the 8th July, 1932, between noon and 1 p. m., a meteorite was observed to fall in the Khangpur pargana, Ghazipur district, United Provinces, and pieces were recovered from a number of villages within a radius of one and a half miles. The weight of the nine fragments recovered totals 1895 grammes, the largest piece weighing 877 grammes. It is a stone meteorite, and a description is in course of preparation.

**Rangoon Office.**

19. In the Rangoon Office, Mr. L. R. Sharma continued his duties as Chemical Assistant to the Burma Circle. Up to November, 1932, 28 specimens were received and reported on, out of which 5 were quantitatively determined. They included iron-ores, lead-ores and slags, copper-ores, and various crystalline rocks and rock-forming minerals.

In addition to his duties as Chemical Assistant Mr. Sharma was responsible for the Museum collections, which, consequent on the removal of the office to the Old Hanthawaddy Court building, had to be re-arranged. Advantage was taken of the re-arrangement to check all the specimens both in store and in the show cases and to change all the labels.

The following specimens were presented to the Museum of the Burma Branch Office during the year under review :—

(A) *By the British Burma Petroleum Company, Ltd.*—(1) Shale with sand alternations, from the B. B. D. D. C. Well No. 5, Minlindaung, (depth approximately 3,000 ft.)

(2) Core showing fissure with calcite infiltration, from B. B. D. D. C. Well N. 1, Block 38, (depth approximately 4,600 ft.).

(3) Core containing fossil leaves, Irrawaddian series, Ainggyi, Magwe district.

(B) *By the Burma Oil Company, Ltd.*—(1) Sandstone core, from B. O. C. Well No. 2505, Yenangyaung, (depth approximately 2,800 ft.).

(2) Sandstone core with shale intercalation, and containing carbonised fossil wood, from B. O. C. Well No. 2460, Yenangyaung, (depth approximately 1,000 ft.).

The necessary water-supply facilities have now been installed in the new laboratory and a dark room provided and the new accommodation for the party can be definitely pronounced as not only more commodious but also more convenient than the old premises in Dalhousie Street.

## PALAEONTOLOGY.

20. Mr. D. N. Wadia acted as Palæontologist throughout the year. N. K. N. Aiyengar, Field Collector, assisted the Palæontologist in routine Museum work and in the determination of specimens. K. P. Haran, Museum Assistant, continued the work of cleaning, relabelling, and rearranging the Klipstein collection in the Invertebrate Fossil Gallery until he was relieved by A. B. Dutt, Museum Assistant. M. S. Venkatram, Museum Assistant, continued routine duties connected with Palæontology.

21. During 1932 the following memoirs have been published in the *Palæontologia Indica* :—

(1) G. E. Pilgrim : 'The Fossil Carnivora of India.' Vol. XVIII of the New Series.

(2) F. R. Cowper Reed : 'New Fossils from the Agglomeratic Slate Series of Kashmir.' Memoir No. 1, Vol. XX of the New Series.

(3) B. Sahni : '*Homoxylon rajmahalense*, gen. et sp. nov., a fossil angiospermous wood, devoid of vessels, from the Rajmahal Hills, Bihar.' Memoir No. 2, Vol. XX of the New Series.

(4) B. Sahni : 'A Petrified *Williamsonia* (*W. sewardiana*, sp. nov.) from the Rajmahal Hills, India' Memoir No. 3, Vol. XX of the New Series.

The following papers of palæontological interest have appeared in the Records :—

(1) 'Note on the supposed occurrence of *Chonetes* in the Krol limestone near Solon', by J. B. Auden. (Vol. LXV, Pt. 4).

(2) 'Rudistæ from Eastern Persia', by Othmar Kühn. (Vol. LXVI, Pt. 2).

(3) 'Note on some Lower Palæozoic Fossils from the Southern Shan States', by F. R. Cowper Reed. (Vol. LXV, Pt. 2).

(4) 'On some Fossil Plants from the Parsora Series, Rewa', by A. C. Seward. (Vol. LXVI, Pt. 2).

(5) 'Note on an Ammonite from Ramri Island', by G. de P. Cotter. (Vol. LXVI, Pt. 2).

The following papers of palæontological interest are in the Press, and are expected to be published in 1933.

*Palaeontologia Indica.*

(1) L. F. Spath: 'Revision of the Jurassic Cephalopod Fauna of Kachh.' Vol. IX, Memoir No. 2, Part VI of the New Series.

(2) Von Huene and C. A. Matley: 'The Cretaceous Saurischia and Ornithischia of the Central Provinces of India.' Vol. XXI, Memoir No. 1 of the New Series.

*Records.*

(3) Carl O. Dunbar: 'Stratigraphic Significance of the Fusulinids of the Lower Productus Limestone of the Salt Range.'

(4) B. Sahni: '*Dadoxylon zalesskyi*, a new species of Cordaitean trees from the Lower Gondwanas of India.'

(5) B. Sahni: 'A Fossil pentalocular fruit from Pondicherry.'

Vertebrates.

22. Dr. G. E. Pilgrim, having completed his memoir on the Fossil Carnivora of India, is now engaged in studying the large collection of fossil Cavicornia from the Upper Tertiaries of various parts of India. The results of his studies are expected to be published in the *Palaeontologia Indica*.

Dr. C. A. Matley, who has been touring in the Central Provinces since November, 1932, in charge of the Percy Sladen Trust Expedition, has furnished an interim report of his activities: two broken ribs of a Dinosaur and a portion of a scapula of *Antarctosaurus*, another Dinosaur, have been obtained at Bara Simla, near Jubbulpore.

Dr. Matley has collected many remains of Upper Cretaceous reptiles from near the village of Pijdura, (Pisdura of the old maps) in the Chanda District, the locality originally discovered by the Rev. S. Hislop in 1860. These include several fragments of Dinosaurian jaws, 85 vertebral centra, numerous ribs, broken limb bones, metapodials and phalanges. Over a hundred pieces of the carapace of chelonians have been obtained, from the surface rocks mostly; but the most striking find so far is the abundance of coprolites in the Pijdura area, occurring on the surface in an excellent state of preservation, showing intestinal impressions. Other fossils from the same locality include a fish vertebra, numerous *Bullinus*, *Paludina*, *Limnaca*, *Unio*, etc.

The skull of *Hydaspitherium megacephalum*, Lyd., one of the most perfectly preserved of our types of fossil giraffes, has been cleaned and further developed from the hard, adhering rock-matrix, with the result that the anatomical details of the basal cranial portion and of the palatine are now better exposed. Two requests for the supply of casts of this fossil have been received from American Museums, and further similar requests are anticipated.

Coloured plaster-casts of the fossil remains of the lately described Peking Man (*Sinanthropus pekinensis*, Black) have been received through Prof. Davidson Black of the Peiping Union Medical College, in part exchange for a complete set of coloured plaster-casts of the fossil anthropoid apes of India stored in our Museum. These casts, beautifully executed from the original fossil, form a valuable acquisition to the Siwalik Gallery of the Museum.

**Invertebrates.**

23. The checking and re-arrangement in stratigraphic order of the fossil collections in the Invertebrate Gallery has progressed considerably during the year under review, resulting in economy of space and ready accessibility of individual specimens. The cleaning of the large Klipstein collections has been finished, but the re-naming of a number of specimens belonging to these old collections, necessitated by recent changes in nomenclature of genera and species, has yet to be taken in hand.

The types and duplicates of the Jurassic brachiopoda of Cutch described by Dr. F. L. Kitchin in *Pal. Ind.*, Ser. IX, Vol. III, have been returned to the Museum during the year.

The duplicates of the Jurassic corals of Cutch, described by the late Prof. J. W. Gregory in *Pal. Ind.*, Ser. IX, Vol. II, have also been received back, and the numerous well-preserved duplicates of the corals forming this extensive collection are being distribution to the institutions selected by Prof. Gregory under instructions from the Director.

Reference was made in last year's report to the collections of fossils from Persia, obtained by Dr. Pilgrim and Mr. Tipper, taken by Mr. E. L. G. Clegg to England for study. Out of these fossils, the group of *Rudistae* from East Persia was studied by Dr. Othmar Kühn of the Natural History Museum, Vienna. Dr. Kühn's paper describing this highly interesting collection was published in *Records*, Vol. LXVI, Pt. 1, (1932).

Mr. Clegg has submitted a paper on the *Echihnoidae* of Persia, while the lamellibranchs, corals and foraminifera of the same collection are being examined by Messrs. L. R. Cox and H. D. Thomas of the British Museum of Natural History, London, and A. G. Brighton of the Sedgwick Museum, Cambridge, respectively.

The voluminous assemblage of fossils obtained from a limestone bed underlying the Warkali beds of Quilon, Travancore State, mostly lamellibranchs and gastropods, which was taken by Dr. A. K. Dey to England for study in 1930, has been fully worked out by him during his study leave. In course of his work Dr. Dey visited various museums in Europe for comparison and description of a number of new species contained in the collection.

Mention was made in last year's General Report to the examination of the Neemuch fossils, found by Mr. H. C. Jones, many years ago, in the Suket shales of the Vindhyans of Central India, by Dr. F. Chapman, Commonwealth Palæontologist, National Museum, Melbourne. After examination of a further set of fossils from the same area sent to him last year, Dr. Chapman has definitely identified one new species of *Obolella* from the collection, and has created a new genus *Fermoria* with three new species. The latter species are, *Fermoria minima*, *F. tripartita* and *F. granulosa*. *Fermoria minima* replaces *Neobolus minima* announced in the General Report for 1931. The new species of *Obolella* is *O. jonesi*, Chapman. More material is being sent to Dr. Chapman for further study and in-

vestigation of these interesting fossils, the earliest definite organic remains occurring in the rocks of the Peninsula.

The large and interesting collections of fossils, mostly graptolites, made by Mr. V. P. Sondhi from the Ordovician rocks of Southern Shan States, Burma, in 1931, are being sent to Dr. F. R. Cowper Reed of the Sedgwick Museum, Cambridge, for examination and description.

The trilobites and brachiopods found by Mr. D. N. Wadia in the Slate series at the base of the Palæozoic in the Baramula district of N. W. Kashmir show affinities with Cambrian genera. A Cambrian fauna has so far not been found in Kashmir or in other parts of the Himalaya to the south of the crystalline axis. But as conclusive results as to the precise age of these fossils cannot be arrived at locally in the absence of sufficient material for comparative study, the collection has been sent to Dr. F. R. Cowper Reed, whose wide acquaintance with the older Palæozoic faunas from many parts of the world will enable him to settle the age of the fossils definitely.

Fossil corals, foraminifera and belemnites collected by Captain Bomford, R.E. from North-West Baluchistan were forwarded to this Department by the Director, Geodetic Survey of India, Dehra Dun, for identification. The collection was found to include fossils ranging in age from Jurassic to Miocene, derived from localities situated either in the geologically surveyed area of Baluchistan, or on the probable extensions of the outcrops mapped.

Plants.

24. Prof. B. Sahni has completed his revision of the coniferous plants of the Gondwana flora dealing with (*a*) Impressions and Incrustations and (*b*) Petrifactions. They have been published in Vol. XI, Pts. I and II, respectively, of the New Series of the *Palaeontologia Indica*. Prof. Sahni is now undertaking the revision of the fossil Monocotyledons of India (Pt. III of the Revision)—material for which is being sent to him from the Survey collections.

In course of his examination of the fossil material taken for study to Europe, Mr. H. Crookshank has found, in specimens belonging to the Jabalpur series, fern-fronds of a species of *Hausmannia ?*—a genus not previously observed in India. The interest of this frond is that it is common in European floras of this period, but till recently had not been found in the Southern hemisphere.

Recently *Hausmannia* has been found in the Antarctic, from rocks homotaxial with the Upper Gondwanas of India.

During the course of fieldwork in the Punjab Salt Range, Mr. E. R. Gee found carbonised plant fragments within the Salt Marl of the following localities:—

(i) In the Kalra Wahan, about 1¾ miles south of Changeanwali (32° 36′ 30″: 72° 27′ 30″).

(ii) In the Warik Nadi, about three miles W. S. W. of Nali (32° 29′: 72° 20′).

(iii) Between the Sujowal and Buggy seams of the northeastern end of the Mayo Salt Mine, Khewra (32° 39′: 73° 0′).

A new horizon including a Lower Gondwana flora was also discovered. The exact locality is at the junction of the two streams just north-east of point 1850, two miles S. S. E. of Kathwai Rest House (32° 29′: 72° 12′) where fairly well-preserved impressions of *Glossopteris*, etc., and a few small lamellibranch casts, occur in carbonaceous shales some 25 to 28 feet thick separated from the underlying Talchir boulder-bed by some 9 feet of sandstones and sandy shales. This horizon is considerably lower in the stratigraphical sequence than the one discovered within the Productus Limestones at Warcha.

**Donations.**

25. During the year under review, presentation of fossils were made to the following institutions:—

*The Texas Christian University, Texas.*—A small collection of fossils from the *Cardita beaumonti* beds of Sind, through Prof. G. Scott.

*St. Xavier's College, Bombay.*—A representative collection of about 150 fossils consisting of vertebrates, invertebrates and plants.

*Presidency College, Calcutta.*—Four specimens of *Spirigerella* presented to Mr. A. Sen, Calcutta University research student, through Prof. H. C. Das Gupta.

*Hailey College of Commerce, Lahore.*—A small collection of the common genera of fossil vertebrates and invertebrates.

*University of Basel, Basel.*—A collection of fossil invertebrates from the Permo-Carboniferous of the Salt Range and Trias of the Himalayas, through Prof. A. Buxtorf.

During the year donations of fossils or casts of fossils were received either by exchange or by presentation from the following institutions :—

*Royal School of Mines, South Kensington, London.*—A representative collection of invertebrate fossils from the Jurassic of England. (Through Prof. Morley Davies).

*Cenozoic Laboratory, Geological Survey of China and the Department of Anatomy, Peking Union Medical College, Peking, China.*—Plaster-casts of the skull of *Sinanthropus pekinensis*, Black. (Through Prof. Davidson Black).

The following fossils were sent on loan during the year :—

Some *Fusulinids* from Chitral, Afghanistan and Kehsi Mansam were sent to Prof. Carl. O. Dunbar of the Peabody Museum of Natural History, New Haven, Connecticut.

Four types of fossil echinoids belonging to each of the genera *Sismondia* and *Plesiolampas* were despatched to Mr. A. G. Brighton of the Sedgwick Museum, Cambridge, for study.

## ECONOMIC ENQUIRIES.

### Asbestos.

**Cuddapah and Kurnool districts, Madras.**

26. In continuation of the work carried out by Dr. C. S. Fox[1] in 1930 Mr. A. L. Coulson made an exhaustive examination of the asbestos occurrences in the Pulivendla taluk of the Cuddapah district. He followed the contacts between the Vaimpalli limestones of the Cuddapah system and the intrusive basalt and dolerite sills associated with them, along the strike of the rocks through the Anantapur district as far north as Kurnool town. Apart from the Brahmanapalle (14° 25′ : 78° 12′) occurrences, Mr. Coulson noted asbestos at Rajupalem (14° 26′ : 78° 31′) in the Kamalapuram taluk and near Vempalle (15° 22′ : 78° 28′) in the Pulivendla taluk of the Cuddapah district; also near Malkapuram (15° 20′ : 77° 59′) in the Dhone taluk and Joharapuram (15° 49′ : 78° 3′) in the Kurnool taluk of the Kurnool district. None of these deposits is of the quality or extent of the Brahmanapalle deposits. The results of Mr. Coulson's investigations will be embodied in a separate memoir.

[1] *Rec. Geol. Surv. Ind.*, LXV, p. 34, (1931).

## Barytes.

**Gangpur State, Bihar and Orissa.**

27. Dr. Krishnan records an occurrence of barytes half a mile to the east of Khatangtola (22° 22′ : 85° 4′), in Gangpur State, barely 50 yards from the Singhbhum boundary. The country rock is mica-schist striking N.-S. In April, 1931, when Dr. Krishnan visited the locality, the vein was being opened up by Mr. W. S. Young of Kalunga, by means of a pit. The vein is about three feet wide and contains some quartz. On account of staining, about 50 per cent. of the vein material has to be rejected. The slight rise in ground where the vein occurs is about 100 yards long, and the vein may be expected to extend over most of this. The locality is about 6 miles N. N. W. of Jaraikela station, B. N. Ry., and about a mile to the N. W. of Kolpotka (22° 21′ 30″ : 85° 5′ 30″), whence also barytes has been reported. [1]

**Cuddapah, Anantapur and Kurnool districts, Madras.**

28. The results of Mr. A. L. Coulson's investigation of the barytes resources of the Ceded Districts of Madras will be published shortly in the form of a separate memoir.[2] Mr. Coulson gives a list of 60 localities, comprised of 13 in the Cuddapah district (of which 8 are in the Pulivendla taluk), 11 in the Anantapur district (of which 8 are in the Tadpatri taluk), and 36 in the Kurnool district (of which 29 are in the Dhone taluk). Only 5 of these occurrences have been previously recorded.

Most of the barytes occurs either in replacement or fissure veins in the Vaimpalli limestones, or in the intrusive dolerite and basalt sills associated with them, of the Papaghni series of the Cuddapah system. The origin of the barytes is discussed in full in Mr. Coulson's memoir. The result of this work is to show that in these deposits we have the largest reserves of barytes in India. One deposit, Kottapalle (14° 22′ : 78° 21′) in the Cuddapah district, is estimated by Mr. Coulson to contain 30,000 tons in the first 20 feet of depth. A second deposit, Mutssukota (14° 51′ : 77° 52′) in the Anantapur district is estimated on certain assumptions to contain 75,000 tons. A third, Balapalapalle (15° 27′ : 78° 6′) in the Kurnool district, has been worked by a succession of concessionaires, amongst whom was the late Mr. A. Ghose, who appears to have been the

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 31, (1929).
[2] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, (*in the press*).

pioneer in the development of the barytes industry in this part of India. The development of these deposits is, however, still only in its infancy and there is much scope for increased production. They can supply the needs of India at her present rate of consumption (just over 10,000 tons in 1931) for some years to come.

## Building Materials.

**Bonai and Gangpur States, Bihar and Orissa.**

29. Dr. Krishnan reports the occurrence of several patches of a light pink *granite-gneiss* in the neighbourhood of Jara (22° 1′ : 84° 39′) in Bonai State. A light coloured medium-grained *granite* occurs near Dalripali (21° 58′ : 83° 55′) in Gangpur State. The hill near Gomhardih (22° 7′ : 83° 54′) contains a *micaceous quartz-schist* that splits up into slabs some of which measure up to about 6 feet by 3 feet. These, according to Dr. Krishnan, are suitable for use as paving stones for floors.

**Panch Mahals, Bombay.**

30. Extensive occurrences of *slate* have been noted by Mr. B. C. Gupta in Aravallis of the Jhalod taluka in the Panch Mahals district, Bombay Presidency. Extensive quarries have been developed about 1½ miles south of Jhalod town. Roofing slates and slabs up to 6 feet by 4 feet are obtainable.

**Cuddapah district, Madras.**

31. According to Mr. A. L. Coulson Bairenkonda quartzite (a handsome dark red fine-grained stone from the lower stage of the Nallamalai series of the Cuddapah system) is quarried from Sirigepalle (14° 54′ : 78° 7′) in the Jammalamadugu taluk of the Cuddapah district, and is carted to places as far distant as Gooty in the Anantapur district for use for drinking-troughs, door-posts, etc.

**Kurnool district, Madras.**

32. One of the rocks most commonly quarried for use as a building stone in the Kurnool district is the flaggy Jammalamadugu limestone which is a constituent stage of the Kurnool series. King has mentioned this use of the Narji limestones in the Cuddapah district[1], the Narjis forming the lower sub-stage of the Jammalamadugus. Mr. A. L. Coulson noted that there is a thriving trade in building stones in the vicinity of Betamcherla (15° 27′ : 78° 8′) in the Dhone taluk of the Kurnool district. The hills to the east of

[1] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, p. 70, (1872).

that large village are composed of horizontal Kurnool rocks: Banaganpallis at the base, and then Jammalamadugus capped usually by Paniams. The Jammalamadugu flaggy limestones are easily quarried and the hillsides in this rock from Betamcherla towards Bugganipalle contain many quarries. Mr. Coulson also noted abundant quarries throughout the Kurnool taluk of the same district.

## Ceramic Materials.

33. *Fire-clay.*—Dr. Krishnan reports the occurrence of a buff to light grey shale at Kipsera (21° 59′ : 83° 47′) in Gangpur State. It possesses good plascity and resists heat at 1,400°C. After burning it becomes practically white in colour but contracts about 20 per cent. in volume. The shale extends for about four furlongs in a south-east direction from Kipsera village, the width of the exposure being about 200 yards.

**Gangpur State, Bihar and Orissa.**

34. *Kaolin and quartz sand.*—A specimen of Barakar sandstone collected by Dr. Krishnan from a spot one mile N. W. of Amatpani (22° 12′ 30″ : 83° 39′) in Gangpur State, at the head of a steep-sided valley, was crushed to pass through a 60-mesh sieve and elutriated, giving 17·8 per cent. of fine clay and 82·2 per cent. of quartz sand. The clay is white and plastic and contracts by about 12 per cent. of its volume on burning at 1,400°C., withoutf using. It will be suitable as a filler because of its white colour.

The sand recovered is found to be pure quartz with less than one-half per cent. of other minerals. It should be suitable for making glass, provided sufficient quantities could be proved to occur there.

35. *Quartzite.*—A white and practically pure quartzite is reported by Dr. Krishnan to occur in the hill about a mile west of Jara (22° 1′ : 84° 39′). It contains a few rare mica flakes and crystals of kyanite. The crushed and screened rock should give quartz of high purity.

**Bonai State, Bihar and Orissa.**

## Coal.

36. Outcrops of coal were noted by Dr. Krishnan at several places along the Baisundar *nala* and its tributaries between Rattansara (22° 4′ : 83° 40′) and Dulanga (21° 57′ : 83° 48′) in the Hingir Zemindari of the Gangpur State. Several of the outcrops were examined

**Gangpur State, Bihar and Orissa.**

by the coal mining company working at Rampur (Sambalpur district), but the results are said to have been disappointing.

A section containing coal seams with intercalated shale partings is exposed on the left bank of the Baisundar *nala* just above its junction with a tributary stream north of Gopalpur (22° 3′ : 83° 42′). A specimen taken from apparently the best part of this section was analysed in the laboratory with the following result:—

| | Per cent. |
|---|---|
| Moisture | 4·24 |
| Volatile matter | 32·98 |
| Fixed carbon | 43·74 |
| Ash | 19·04 |
| | 100·00 |

Sp. gr., 1·427 ; does not cake ; ash white.

In the same section was found a bed, about 9 to 12 inches thick, composed of a mixture of granular vitrain and powdery red ochre. The vitrain gave on analysis :—[1]

| | Per cent. |
|---|---|
| Moisture | 6·80 |
| Volatile matter | 32·62 |
| Fixed carbon | 59·64 |
| Ash | 0·94 |
| | 100·00 |

Sp. gr., 1·346 ; does not cake ; ash drab.

**Betul District, Central Provinces.**

37. As a result of his examination of the various coalfields in the Betul district—Sonada ; Gurgunda (Suki) ; Mardanpur (Machna) ; Golai ; Dulhera ; Pathakhera ; Bamhanwara (west of) ; and Khapa (north of)—Dr. Fox considers that the only one likely to prove commercially profitable is that of Pathakhera. It is, however, somewhat isolated and requires further exploration by boring. In the Chhindwara district the outcrops of coal measures in the northern tributaries of the Tawa river are merely of interest as showing the continuity of the Barakars from the Panch Valley and Kanhan coalfields into those of the Betul district. It is not necessary to

[1] *Op. cit.*, X, p. 161, (1873).

give further details in regard to the Betul coalfields here as Dr. Fox has prepared a memoir (to be published as Vol. LIX) on the Gondwana Coalfields of India. In this memoir, in the chapter dealing with the Satpura region, a brief description of each area will be found together with references for fuller particulars.

## Copper-ore.

**Kurnool district, Madras.**

38. Mr. A. L. Coulson visited the two small quartz-veins mentioned by King as situated in the deep bay in the hills east of Somadulpilly [1] (Somayajulapalle 15° 35′ : 78° 11′), in the Kurnool taluk, and found traces of chalcopyrite in the northern vein. He noted secondary malachite in thin quartz-veins in trap, 1¼ miles south-east of Kalava (15° 37′ : 78° 12′). He did not visit the old workings seen by Foote in the Gummani Konda valley, which appear to be about 2¾ miles south-west of Gani (15° 40′ : 78° 19′) in the Nandyal taluk of the Kurnool district, but noted old pits for copper-ores 1⅝ miles S. S. E. of Gani along the course of a quartz-reef, which appeared to be intricately mixed up with trap. Secondary malachite and azurite were seen.

All these occurrences are of scientific interest only.

## Diamonds.

**Kurnool district, Madras.**

39. During his investigation of the barytes and asbestos deposits of the Ceded Districts of Madras, Mr. A. L. Coulson frequently observed old diamond pits sunk in the basal gritty beds of the Banganapalli group of the Kurnool series. Most of these pits have been recorded by King in his memoir of the Cuddapah and Kurnool systems[2] ; but five furlongs S. by E. of Chennakkapalle (15° 39′ : 18° 20′) in the Nandyal taluk of the Kurnool district are some that appear to have escaped King's notice. The most numerous pits occur near the villages of Balapuram, Repalle and Virayapalle (15° 32′ : 78° 5′) in the Dhone taluk of the same district. Certain of these near Balapuram (15° 32′ : 78° 4′) are said to have been sunk fairly recently by the late Mr. A. Ghose. Mr. Coulson suggests that the diamonds in the Banganapalli beds have been derived by

[1] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, p. 268-269, (1872).
[2] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, p. 106, (1872).

weathering from certain trap sills, intrusive into the Vaimpallis and the Cheyairs, the series immediately above the Papaghnis. These sills are thought to be of the same age as the decomposed basic rock found at the diamondiferous locality of Wajra Karur in the Anantapur district.[1] This suggestion is in agreement with that of the late Mr. Vredenburg[2] that the diamonds of the Vindhyan conglomerates of Central India and of the Kurnool conglomerates of Southern India are both derived from basic dykes of Bijawar age traversing an older granitic or gneissic terrain. Vredenburg regarded the Cheyairs as the South Indian equivalents of the Bijawars.

## Dolomite.

**Gangpur State, Bihar and Orissa.**

40. Dr. Krishnan reports that dolomitic marble is exposed in the *nala* just north of Lifripara (22° 7′ : 83° 49′) in Gangpur State, for a length of 500 yards along the strike and 40 to 50 yards across. Two specimens collected from different parts of the exposure were analysed with the following result :—

| | (43/175) Per cent. | (43/176) Per cent. |
|---|---|---|
| Silica | 3·04 | 0·20 |
| Alumina and ferric oxide | 1·30 | 0·92 |
| Lime | 30·73 | 30·54 |
| Magnesia | 20·67 | 20·78 |
| Loss on ignition | 43·48 | 48·02 |
| TOTAL | 99·22 | 100·46 |
| Specific gravity | 2·85 | 2·88 |

The analyses show that these are nearly pure dolomite. Some parts of the exposure are more siliceous. The locality is about 20 miles from the railway, and in view of the fact that dolomite mining even at places very near the railway, *e.g.*, at Amghat (22° 15′ : 84° 37′) and Usra (22° 15′ : 84° 42′), has been stopped within the last two or three years for lack of demand, the exposure at Lifripara does not seem to be of immediate importance.

[1] R. Bruce Foote, *Rec. Geol. Surv. Ind.*, XXII, pp. 39-49, (1889); Philip Lake, *op., cit.*, XXIII, pp. 69-72, (1890).
[2] *Op. cit.*, XXXIII, pp. 280-281, (1906).

## Engineering and Allied Questions.

**Mor River Reservoir, Bengal.**

41. Dr. J. A. Dunn was asked to report on the dam-site at Masanjor in the Santal Parganas, where it is proposed to construct a dam across the Mor River close to mile 83 on the Dumka-Suri road. At this point the river is about 400 feet wide and flows between two hills the bases of which are about 1,600 feet apart. There is an alluvial flat 300 to 400 feet wide on either side of the river up to the foot of each hill. Granite-gneiss (in part hypersthenic) crops out in both hills and also along either bank of the river. Dr. Dunn pointed out what he considered to be the most favourable line for the dam, and reported that the granite-gneiss will form an ideal foundation for a masonry or other type of structure, provided the foundations are taken down until reasonably fresh rock is encountered. Dr. Dunn recommended work to ascertain the depth of alluvium between either bank and the hills, the depth of sand in the river bed, and the depth to which the weathered granite must be removed to expose rock sufficiently fresh for the foundations.

**Myitnge *chaung* reservoir projects, Mergui District, Burma.**

42. At the instance of the Public Health Department of the Government of Burma, Mr. P. Leicester reported on two reservoir schemes on the Myitnge *chaung* in the Mergui district of the Tenasserim division. The area in which the reservoir sites are situated (12° 27′ : 98° 43′) lies about 7 miles due east of Mergui and was geologically surveyed by Dr. Heron in the field season of 1920-21. Both catchment areas lie on impervious rocks of the Mergui series, although an intrusion of coarse-grained tourmaline-granite about 200 yards broad cuts across the more southerly area about one furlong above the dam site.

The dam sites examined are situated on banded and jointed quartzites of the Mergui series varying from a pink fine-grained variety to purple or white schistose varieties. Where the ground is well-drained, as on steep slopes and in the river bed, the rock is fresh, but on the gentler wooded slopes it is decomposed to considerable depths. The dip of the quartzites is downstream and the joints of the rocks prominent.

Mr. Leicester recommended the abandoning of the selected site of Reservoir No. 1 (the more northerly) on account of extremely soft intrusive veins of decomposed granitic rock, which gave no signs of hardening in depth, but was able to select another more satis-

factory one free from granitic veins that would affect the stability of the site.

The site selected for the dam of Reservoir No. 2 was found to be satisfactory; it is situated on solid compact quartzite, although a badly fractured quartz vein that crosses it will have to be excavated and the joints carefully grouted to a considerable depth. The obvious geological objections to the sites are the downstream dip and the prominent jointing; but as Mr. Leicester points out, they are of minor importance and their severity is lessened owing to the dip being steep and the rocks compact, massive and stable, whilst the joints close in depth.

Arwa Glaciers, Garhwal, United Provinces.

43. In June, Mr. Auden and Mr. L. B. Gilbert, Executive Engineer, Kumaon Provincial Division, paid a joint visit to the Arwa valley in British Garhwal, in order to examine the glacier which Mr. Smythe and the Kamet party considered might block the valley.[1] A joint paper by these officers has already been published in the *Records*.[2] The glacier (30° 52′ : 79° 26′) was mapped, and cairns placed to assist those making later observations. The authors consider that, while there is no immediate danger of a blockage of the valley with the formation of a lake, the nature of the glacier is such that a sudden advance is possible. They recommended an annual inspection.

## Gold.

Southern Shan States, Burma.

44. For a long time, according to Mr. Sondhi, gold has been known to the local inhabitants to occur on the western slopes of the Mwe-daw hill-mass (20° 39′ : 96° 28′ 30″) which lies to the west of Kalaw in the Southern Shan States: evidence of former activity in the search for the metal is met to this day in the pits dug about half way down the slope into and along beds of marble and siliceous limestone, which have been altered from almost pure limestones by igneous intrusions. That the presence of gold in the soil derived from the above rocks was also fully known is indicated by numerous tailing dumps scattered over the area, where pan-washing was practised.

[1] *Geographical Journal*, LXXIX, p. 6, (1932). 'Kamet Conquered' by F. S. Smythe, pp. 275, 276, (1932).
[2] *Rec. Geol. Surv. Ind.*, LXVI, Pt. 3, (1932).

Just before the last European war systematic prospecting by modern methods was started and the dilapidated remains of four horizontal tunnels still exist, but unfortunately no records seem to either as to the extent of the work or of the persons be available by whom it was carried out.

Since then, the area has been held on prospecting licence, but, although this has been renewed continuously, no serious effort was made to investigate the possibilities of its exploitation until recently, when Mr. E. C. M. Garrett of the Shan States Silver-Lead Corporation Limited, Bawzaing, acquired a prospecting licence, which has been transferred to the Kafue Copper Development Co., Ltd., a company operating in South Africa.

At present a detailed investigation is being carried out; the old tunnels are being cleared; and qualitative analyses of the samples taken are giving, it is reported, very encouraging results.

In Mr. Sondhi's opinion the origin of the gold is to be ascribed to the dioritic and granitic intrusions into the Kalaw coal-measure series. Diorite crops out in an irregular but almost continuous exposure from a little south-east of Mwe-daw to the latitude of Law (20° 41′ : 96° 27′), a distance of over four miles. It is a porphyritic, holocrystalline and medium-grained rock, consisting mostly of large phenocrysts of zoned and partially saussuritised felspar, and hornblende. East-north-east of Mwe-daw, a typical biotite-granite has been found.

As a result of the intrusions the limestone beds have been either completely silicified or metamorphosed to marble and large quantities of wollastonite have been produced. The richest gold values have been obtained in a highly crushed and recemented fault-rock accompanied by secondarily deposited silica, hematite, and malachite.

Whether gold occurs in localised pockets or follows particular zones will it is hoped be made clear in the course of the detailed investigations now in progress.

Copper staining and pockets and strings of malachite are frequently met in the gold-bearing rocks, but the data so far obtained are not sufficient to enable one to form an idea of the true disposition and extent of the ore.

**Jubbulpore district, Central Provinces.**

45. Dr. M. S. Krishnan was deputed, in March, 1932, to visit the area south-east of Sleemanabad, Jubbulpore district, where some zones of crushed conglomerate were being prospected for gold by the Bauxite and Chemical Development Syndicate Ltd. The area

occupies the southern three-fifths of sheet 64 A/6 (scale 1 inch=1 mile).

The rocks occurring here were originally described by Hacket as Bijawars (in his manuscript report for the field seasons, 1869-70 and 1870-71), and regarded later by myself as more appropriately to be assigned to the Dharwars.[1] They are seen to be folded into a series of isoclines, the strike of the formations being E. 35° N.-W. 35°S. and the strike of the foliation E. 10° N.-W. 10°S. Two or more systems of joints are present in the rocks and especially in the conglomerates.

Fine-grained dolomitic marbles occur in the northern part of the area. These dip fairly steeply towards the S. S. E., under a series composed mainly of mica-schists, which occupy the greater part of the southern half of the sheet. Several lenticular sills of epidiorite occur amidst the schists as well as in the dolomitic marbles. There are several prominent bands of crushed conglomerate forming ridges in the area. The whole series is traversed by quartz-veins of a late age. On the basis of general lithological resemblances, Dr. Krishnan agrees in regarding these rocks as Dharwarian, comparing them with the Dharwarian rocks of Singhbhum and Gangpur in Bihar and Orissa.

The main interest in the area centres around the conglomerates, because of their resemblance to some forms of banket, the auriferous rock of the Rand in South Africa. They vary in thickness from a few feet to about one hundred feet, and pinch out after some distance when followed along the strike. Three types of conglomerate have been recognised :-

1. This contains large pebbles of quartzite in a fine-grained matrix, the pebbles being well-rounded and apparently water-worn. Pyrite and limonite are seen in the matrix but practically no chlorite. Under the microscope large grains of quartz are seen to be surrounded by much finer, granulated quartz. Effects of shearing can be seen, but not prominently.
2. This is more highly crushed and sheared than the first type. The pebbles are composed of quartzite and also chalcedonic quartz. The matrix shows quartz, chlorite, sericite and ferruginous matter.

[1] *Mem. Geol. Surv. Ind.*, XXXVII, p. 805, (1909).

3. This occurs only in a solitary exposure about twenty feet thick, near Bhadanpur (23° 34′ : 80° 22′) and shows pebbles of dark grey banded iron-o[illegible]ite in addition to ordinary quartzite.

In the first type at least, the sedimenta[illegible] of the pebbles is clear. Evidences of crushing and shearing are seen in all, and particularly in the second type. Dr. Krishnan visited several sections of the conglomerates in company with the mining engineers who were conducting the prospecting operations. At the time of his visit, a large number of assays of properly taken samples had been made for determining the gold content of the conglomerates and a few other rocks of the area. These gave, in general, gold values ranging from 0·2 to 0·8 dwt. per ton. There is little evidence of sulphide mineralisation in any part of the area. The veins of bluish quartz gave, however, gold values up to 3 or 4 dwts. per ton ; but these are so sparsely and sporadically distributed that they are not likely to yield commercially workable quantities of ore. The uniformly poor assay results of the conglomerates indicate, in Dr. Krishnan's opinion, that the gold content is a primary constituent of the original sediments and is unconnected with any later mineralisation. Though the prospecting operations have opened up only the weathered zone, it is thought that the prospects are poor for any enrichment of gold content with depth.

## Gypsum.

**Sirmur State, Punjab.**

46. Mr. Auden records the presence of gypsum in the Krol limestones in the following localities :—

(1) *Bhaunrari* (30° 47′ : 77° 14′) in Krol D limestones, in pockets probably due to replacement.

(2) *Ridana* (30° 33′ : 77° 45′) in Krol A limestones, in bedded form and probably an original deposit.

Specific gravities of the material from Ridana show that some of it is an admixture of gypsum and anhydrite.

These deposits are very small, and most certainly do not deserve exploitation.

## Iron-ore.

Kurnool district, Madras.

It is intere[illegible] record that attention has latterly been directed to the iron-o[illegible] by King as occurring along the course of his Gunnygull fault[1] in lands belonging to the village of Veldurti (15° 33′ : 77° 56′) in the Dhone taluk of the Kurnool district. Between 2,000 and 3,000 tons were excavated and left on the surface of the plot by a licensee in 1925 and the stock became the property of Government. A sample of the ore forwarded to the Geological Survey of India for analysis contained 59·12 per cent. of iron and 16·32 per cent. of silica. The same plot has been granted to another applicant.

## Lead-ore.

Gangpur State, Bihar and Orissa.

48. About a mile to the south-east of Sargipali (22° 3′ 30″ : 83° 55′) and just to the north of hill 1254, Dr. Krishnan noted a trench which is about a mile long, 60 feet wide and 10 to 20 feet deep. It has a nearly E.-W. trend, which corresponds approximately with the strike of the mica-schists forming the country rock. The original depth of the trench must have been much greater, as much of the dumped material at the sides has slid back into the trench. Neither the villagers nor the State authorities have any knowledge of the history of the trench, which undoubtedly indicates some former mining activity. Specimens collected from the dumps showed the presence of galena, some malachite, and a few small crystals which, on testing, proved to be pyromorphite.

In March, 1932, Mr. H. D. Christian, the Superintendent of Gangpur State, had three pits put down at selected points in the trench. One of these, which reached a depth of 21 feet below the floor of the trench, revealed mica-schist veined and impregnated with galena. A sample of this rock, assayed in the Geological Survey Laboratory, gave 4·39 per cent. lead, 0·15 per cent. copper, and 22·2 dwt. silver per ton. Indications of a possible second vein about a quarter of a mile to the north were seen in the form of a few lumps of

[1] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, pp. 277-278, (1872). *See* also A. L. Coulson, *Rec. Geol. Surv. Ind.*, LXVI, Pt. 4, pp. 441-443, (1933).

cerussite, with sometimes a core of galena, obtained from prospecting pits.

## Manganese-ore.

**Panch Mahals, Bombay, and Jhabua State, Central India.**

49. Mr. B. C. Gupta in the course of systematic work in the Panch Mahals and Jhabua State noted two small occurrences of manganese-ore associated with phyllites of Aravalli age. The first of these lies about three miles north of Anas on the B., B. & C. I. Railway. The ore consists of pyrolusite, psilomelane and wad. The other occurrence is near Mandli (22° 57′ : 74° 26′) some four miles further N. N. W., which is the direction of the general strike of the phyllites. At Mandli the bulk of the ore consists of massive psilomelane, but crystalline aggregates of braunite and hollandite with rhodonite and piedmontite (?) also occur. The ore body is irregular in its occurrence and no estimate of the amount of ore accessible for exploitation has been made. Mandli is only some four miles W. N. W. of the well-known deposit of Kajlidongri in Jhabua State.

## Mica.

**Gangpur and Bonai States, Bihar and Orissa.**

50. 'Books' of muscovite not exceeding two inches in diameter were noticed by Dr. Krishnan in veins of pegmatite west of Tangarmunda (22° 5′: 84° 21′ 30″), Gangpur State, and also just south of Potatangar (22° 0′: 84° 33′), Bonai State. These seem to be too full of flaws to be of commercial value.

**Putao district, Burma.**

51. During the year prospecting for mica was carried out by Mr. J. T. O. Barnard in the Putao district of Burma. This country has not been geologically mapped but a traverse was made though it by Dr. Murray Stuart.[1] The pegmatites that carry the mica appear to be associated with the granite mass mapped by Stuart about 10 miles due east of Fort Hertz. In the course of prospecting Mr. Barnard collected about 11 lbs. of mica of saleable though low grade. Big books of mica do occur, but those found up to now have all been very much strained and of no economic value.

[1] *Rec. Geol. Surv. Ind.*, L, p. 241, (1919).

## Ochre.

52. A thin bed composed of a mixture of granular vitrain and powdery red ochre is found, according to Dr. Krishnan, in the upper part of the coal section in the Baisundar *nala* from near its junction with a tributary north of Gopalpur (22° 3′: 83° 42′) for a mile eastwards to a point south of Tiklipara (22° 4′: 83° 44′). The thickness of this bed varies between 9 and 12 inches. The exposures extend from the bank of the *nala* for about a furlong northwards, the dip of the bed being about 15° towards the south. In the weathered portions the ochre is orange-red in colour, but freshly broken lumps show deep cherry-red colour. The quantity of the ochre is good, as it compares well with the standard No. 4 ochre of the Shalimar Paint, Colour and Varnish Co.

**Gangpur State, Bihar and Orissa.**

Dr. Krishnan estimates that about 14,000 tons of ochre are available in this deposit, and possibly much more. An easy process of separation of the ochre from the vitrain should be feasible, the specific gravities of the two constituents being 3·65 and 1·346 respectively.

## Petroleum.

53. Mr. C. T. Barber remained in charge of the office of Resident Geologist, Yenangyaung Oilfield, throughout the year. Among the subjects on which he gave advice was the question of increasing the vacuum applied to wells in the Reserves of the Yenangyaung field. A similar proposal in 1928 was rejected by the Warden of the oilfields on the grounds that while the application of vacuum had increased the production of oil from certain portions of the field, yet, owing to its tendency to vitiate the results of the maintenance and restoration of pressure in adjacent portions of the structure, it had not been established that the application of vacuum had increased the ultimate production of the field; and further, that the increased production of gas under the application of vacuum was not conducive to an increase of the total ultimate production of oil from the field, but was probably having the opposite effect.

**Resident Geologist, Yenangyaung Oilfield.**

**The vacuum problem.**

The fundamental conceptions of the mechanism of the movement of oil through porous reservoirs and of the importance of the conservation of the energy of expansion have undergone little change

since that time, and much of the discussion of the theoretical aspects of the subject have been recapitulations of the views expressed by the interested parties in 1928. The most important of the new arguments advanced by the appellant companies are connected with the enhanced depletion of the known sands in the Reserves, the decreasing influence of gas in bringing oil to the well, and the concomitantly increasing importance of gravity as a factor in production. In addition, the effect of the application of vacuum on the production of wells in the Reserves, since its systematic application in 1923, was much more thoroughly ventilated than in the discussions of 1928.

As a result of lengthy discussion and consideration of these subjects the Warden found—

'(*a*) that the bulk of oil production in the Reserves and their borders is actuated mainly by gravity;

(*b*) that there is no theoretical reason why vacuum should not have the effect of assisting gravity in the movement of oil by the lowering of resistance to such movement;

(*c*) that the graphical evidence submitted and discussed justifies the conclusion that existing vacuum has had a substantially beneficial effect on overall production in the Twingon reserve and its border;

(*d*) that the increase in vacuum for which application has been made does not present a menace to pressure conditions in those portions of the field adjacent to the Reserves and their borders;

(*e*) that the increase in vacuum for which application has been made cannot be regarded as a potential cause of serious operating troubles.'

The Warden concluded that these findings were sufficient to justify the removal of his predecessor's prohibition of increased vacuum in the Reserves. His order permitting an increase in vacuum from 5 to 7½ inches of mercury on and after the 10th of October, 1932, and to 10 inches on and after the 10th April, 1933, is the subject of an appeal to the Commissioner, Magwe Division.

Control of the Oilfield.

54. The Resident Geologist collaborated with the Warden of the oilfields in the revision of the general orders of the Warden. The most important of the objects which it was sought to achieve by the promulgation of new

orders were:—the protection of gas sands from contamination by water, the prevention of the penetration of high pressure sands by wells which are not suitably equipped, a more complete control over the plugging of wells, and the prevention of the intentional drilling of inclined holes. In addition to the inclusion of new or modified orders on these subjects, the codification of the orders has been simplified and a modified system for the submission of reports has been instituted with the object of rendering the requirements less onerous to the operators, but at the same time enhancing the value of the reports.

55. Several confidential reports were submitted on the measurement and assessment to royalty of natural gas and on various problems connected with leasing.

Gas resources of Burma.

56. In connection with his work on the natural gas resources of Burma, Mr. Barber made a detailed survey of the deep test wells that have been drilled in Burma, and his conclusions will be embodied in a memoir on that subject.

57. With the co-operation of the Burmah Oil Company, the Indo-Burma Petroleum Company, Ltd., and the British Burma Petroleum Company, Ltd., and in response to a request from the Director of Civil Aviation for information concerning possible sources of supply of helium in India and Burma, five samples of natural gas from the Yenangyaung, Singu, Indaw and Pyaye fields were forwarded to the Indian Institute of Science for analysis, (including the estimation of the helium content). The results of the analyses are awaited with great interest.

## Salt.

Mayo Salt Mine, Khewra, Punjab.

58. At the end of the field-season, with a view to advising the authorities of the Northern India Salt Revenue Department regarding the probable extension of the seams of rocksalt to the east of the present workings, Mr. E. R. Gee carried out an examination of the Mayo Salt Mine, Khewra (32° 39′ : 73° 0′), Punjab.

He notes that the sequence of seams exposed within the present workings include, in descending order, the following:—

*North Buggy seam*—relatively poor quality salt, 20 to 30 feet thick.

| | |
|---|---|
| *Buggy seam*—good salt with several thin *kallar bands ;* total thickness 100 to 120 feet, but thinning somewhat in the eastern part of the mine.<br>*Sujowal seam*—good quality salt, 20 to 80 feet thick, also thinning in the eastern workings. | These two seams run together in the western part of the mine. |

*Upper Pharwala seams*—two seams of variable thickness and quality, usually not more than 30 to 40 feet in individual thickness.

*Middle Pharwala seam*—represented by poor salt and marl in the western part of the mine, but occurring as a 70 to 80 foot seam of good quality salt in the eastern workings (Chambers 12 to 24).

These seams are separated by bands of marl, which, considering the nature of the deposit, are very constant over wide areas. The beds dip, in general, to the N. N. W., but flatten out in the southern and eastern parts of the mine; whilst in the extreme eastern workings there is evidence of their forming a low anticline pitching gently towards the E. N. E.

The present workings in the Middle Pharwala seam—about which seam in particular advice was required—extend to Chamber 24, where the seam, of good quality, includes one or two lenticular bands of marl. Mr. Gee suggests that to the east of these workings, at least as far east as Chamber 30 and probably to Chamber 35, along the continuation of the line of the South Pharwala tunnel and for several hundred feet to the north, this seam will remain flat or with a gentle northerly dip. He observes, also, that an easterly pitch—particularly around Chambers 27 to 28—will probably cause the seam to occur below the level of this tunnel in the eastern part of its continuation. Provided, however, that the quality of the seam remains good, a large area of workable salt should be available.

## Sapphires.

Kashmir State.

59. On his return from Gilgit, Mr. Wadia had an opportunity of examining the collection of minerals and rocks obtained from the sapphire-mines area of Padar (33° 27′: 76° 23′), Zanskar district, Kashmir, by the officers of the Kashmir Mineral Survey. These mines are situated on the

south flank of the Zanskar range at a distance of about 120 miles south-east from the Burzil pass, along the main tectonic strike of these mountains. The latest published account of the sapphire deposits of Kashmir is by Mr. C. S. Middlemiss[1], according to whom (*loc. cit.*, p. 13) the sapphires occur in lenticles of kaolinised pegmatite, enclosed in, or intrusive in, very much larger lenses of actinolite-tremolite-rock, which are probably local modifications of associated crystalline limestone strata; and these last occur interbedded with biotite-graphite and hornblende and garnetiferous gneisses. According to Mr. Wadia the specimens of these rocks seen in Srinagar contain all the types characteristic of the Salkhala series in the Kishenganga and Kaghan areas, as well as in the Burzil valley. Although an intimate complex of hornblende-granite and crystalline limestone, resulting in tremolitic and actinolitic marble, is often observed in the higher reaches of the Kunhar valley of Hazara, especially in the Buta Kundi and Barawai (Jora) side tributaries, Mr. Wadia has not yet succeeded in definitely detecting corundum in that tract, probably because pegmatites similar to those of Padar have not been found. The results of the investigations of the Kashmir Mineral Survey, however, in an otherwise exactly parallel system of rock formations justify, in Mr. Wadia's opinion, the careful prospecting of the more heavily granitised parts of the Salkhala zone of the Kunhar valley in Kaghan and adjacent parts, north of latitude 34° 54′, in the hope that corundum-bearing pegmatites may be discovered.

## Sulphur.

**Salt Range, Punjab.**

60. Within the Mandiwala gorge, about half a mile north of Salt Chauki, three miles north of Kund (32° 25′ : 72° 13′), Shahpur district, massive gypsum with associated dolomite and bituminous shale, occurring in the upper part of the Salt Marl series, crops out at the base of the western slopes. This vertical grey and white gypsum was noted by Mr. E. R. Gee to contain numerous crystals of iron pyrites, and from the gypsum flowed a spring of clear water charged with sulphuretted hydrogen. This spring deposits very small amounts of yellow sulphur in the vicinity.

[1] 'Precious and Semi-Precious Gemstones of Jammu and Kashmir,' Mineral Survey Reports, Jammu and Kashmir Government, (1931).

## Water.

**Middle portion of Salt Range, Punjab.**

61. The water-supply of the eastern parts of the Salt Range, included within the Jhelum district, has been discussed in previous years[1]. In the course of systematic field-work during the past season Mr. E. R. Gee continued his investigations westwards into the Shahpur district as far west as the area around and north of Jabbi (32° 24′ : 72° 6′).

He observes that in the case of the upland alluvial areas around Pail (32° 38′ : 72° 28′) and Bhadrar (32° 39′ : 72° 30′), the supply from wells is fairly good. In the western part of this area a number of wells taps a permanent supply at a depth of about 40 to 60 feet, though in the eastern portion—around Bhadrar—the water-table is at a greater depth, about 7 to 80 feet, whilst at Dheri (32° 38′ : 72° 30′), on account of an inlier of Salt Marl in the vicinity, the water of one well was saline. He suggests that further supplies of good water would be obtained within the above-mentioned depths in the centres of these alluvial upland valleys. Supplies are similarly obtained from the alluvium and the Kamlial strata in the vicinity of Jaba (32° 38′ : 72° 22′ 30″).

To the west on the Chamil plateau, the few small villages that exist, obtain their supplies either from artificial tanks or from the springs within the Narshinghphoar gorge to the south. Small supplies, (?) perennial, might be obtained from wells sunk within the patches of alluvium in the vicinity of these villages; but the main water reservoir is the lower portion of the Nummulitic Limestones which form this plateau. These limestones are at least 300 feet thick, so that deep borings would be necessary. There is little doubt, however, that such bore-holes, if of wide diameter, would yield a good supply, probably under at least sub-artesian conditions along the southern part of the plateau.

Further west at Sodhi (32° 35′ : 72° 16′), good water from the large spring just south of the village is plentiful, whilst wells sunk in the alluvium of the valley to the east and west of the village obtain a supply at moderate depths. The valley of Kalial (32° 33′ : 72° 18′) is supplied by wells sunk in the alluvium in the western portion of the area, but the actual requirements of the village appear to be met either from large artificial tanks or from a spring arising

[1] *Rec. Geol. Surv. Ind.*, LXIII, pp. 75-77, (1930); LXVI, pp. 77-79, (1932).

out of the Nummulitics to the south. Tiri (32° 32′ : 72° 16′) is also supplied from tanks, though water is also available over a large part of the year in the gorges to the south and east. Wells sunk in the alluvium of the Khura (32° 32′ : 72° 13′) and Sodhi Bala (32° 29′ : 72° 10′) areas meet the needs of the villagers and are used for irrigation: springs also exist in the neighbouring hills.

The requirements of Jalhar (32° 6′ : 72° 15′) are satisfied from relatively shallow wells sunk in the alluvium not far from the lake, and there is no doubt that, by excavating deeper wells to the south and east of the village, water for irrigation purposes would be available. The small villages on the plateau between Jalhar and Jabbi (32° 24′ : 72° 6′) obtain their supplies either from large artificial tanks or from local springs arising usually out of the Productus or the Nummulitic Limestones.

In regard to the larger villages situated on the edge of the plains just south of the Salt Range, Mr. Gee notes that the position is more critical. It is not so much a question of obtaining water, but of obtaining water which is non-saline and fit for human consumption. Wells sunk in the alluvium a short distance south of the Range are almost certain to strike water at moderate depths, but it is equally certain that in the case of the present villages—situated as they are near the alluvial fans of large gorges which drain saline scarp slopes—, the water will be saline. This was found to be so in the case of a well at Katha Masral (32° 31′ : 72° 26′).

At Katha Masral (and the adjoining village of Katha Saghral), Malwal (32° 30′ 30″ : 72° 22′), Mohra (32° 26′ : 72° 17′), and Kund (32° 25′ : 72° 13′) efforts have, therefore, been made to tap the supplies of fresh water in the gorges that intersect the scarp to the north of these villages, above the outcrops of the Salt Marl. Mr. Gee considers that this is the only satisfactory solution of the problem, though he points out that the methods at present in use are distinctly primitive. The water is usually carried in a very *kuchha* mud drain along the side of the lower reaches of the gorges and across the boulder alluvium area to the south. Breaches are, needless to say, very frequent during periods of heavy rain, and in addition, the water is always liable to contamination. A more efficient system is adopted at Kund, and in the case of the villages in the vicinity of the Khushab-Kund road, the water being carried in masonry drains or in pipes from its source within the gorges to the north.

Further west at Sikriala (32° 24′: 72° 10′), and to the south, the needs of the villages are usually met from large artificial tanks. It is unfortunate that the fresh-water springs of Nara (32° 26′: 72° 9′) cannot be piped down the gorge for use in these villages. At Chenki (32° 23′: 72° 7′), a shallow well, sunk in the bed of the gorge a short distance to the north, supplies the inhabitants; whilst at Jabbi, the perennial springs a short distance north of the village are used. The water of the Kohad gorge is saline in the vicinity of Kohad (32° 27′ 30″: 72° 7′ 30″), but further downstream, at least to within 2 miles of the gorge exit, it is apparently fit for human consumption and efforts have been made in the past to construct a *kuchha* drain over the saline southern reaches of the gorge.

**Well site at Khewra, Jhelum district.**

62. In advising the authorities of the Northern India Salt Revenue Department regarding the question of a well for the purpose of augmenting the present supplies of water in the gorge reservoir at Khewra (32° 39′: 73° 0′) Mr. Gee suggested the excavation of a wide diameter well in the faulted synclinal of Nummulitic Limestones in the gorge-bed just south of the reservoir.

## GEOLOGICAL SURVEYS.

**Three Circles.**

63. As a result of retrenchment in the Geological Survey of India the total staff of gazetted officers has been reduced from 36 to 24. After allowing for officers detailed for headquarters work and the Resident Geologist, Yenangyaung, the effective field staff has been reduced from 30 to 18 without allowing for officers on leave during the field season. Owing to the reduction of the number of Superintendents to three the former grouping of officers in the field into 5 parties has had to be modified into three, and as the field of operations of each party is now a very large one it is convenient to use the term Circle, describing the three circles as the Burma Circle, the Northern Circle and the Southern Circle. The terms Northern and Southern Circle are self-explanatory and the boundary between them will vary in position according to convenience. At present work is in progress in the North-West Frontier Province, the Punjab, Rajputana, Northern Bombay and the United Provinces in the Northern Circle; and in the Central Provinces, Bihar and Orissa, Bengal, Assam and the Madras Presidency in the Southern Circle.

64. During the field season 1931-32, the Burma Circle consisted of Dr. J. Coggin Brown (in charge), Messrs. C. T. Barber, P. Leicester and V. P. Sondhi, and Drs. M. R. Sahni and L. A. N. Iyer. On Dr. Coggin Brown proceeding on leave preparatory to retirement at the end of the field season Mr. E. L. G. Clegg took over charge of the party.

**Burma Circle.**

65. Dr. Sahni continued the survey of the Northern Shan States, finishing sheets 93 E/15, and 93 E/14, except for a small area in the north-eastern corner of the latter sheet. In addition he commenced work on sheet 93 E/9, mapping the greater part of the area to the west and south of Namkhan (23° 50′ : 97° 41′) and to the south of the river Shweli, thus extending the area surveyed to the Chinese frontier.

**Northern Shan States.**

The following formations were met with, the Chaung Magyis being intruded by an enormous mass of granite :—

| | |
|---|---|
| Jurassic . . . . . . . . | Namyau series. |
| Devonian-Permian (?) . . . . . | Plateau Limestone. |
| Silurian . . . . . . . . | Namshim sandstone. |
| Ordovician . . . . . . . . | Naungkangyi sandstone. |
| Pre-Cambrian . . . . . . . | Chaung Magyi series. |

The *Chaung Magyis* are the oldest sedimentary rocks mapped in the area and consist mainly of unfossiliferous quartzitic sandstones. They may be of Cambrian or Pre-Cambrian age[1] being usually regarded as the latter.

*Ordovician* rocks occur along the axis of a dome-shaped inlier about six miles S. S. W. of Kutkai (23° 27′ : 97° 57′). They consist of yellowish brown sandstones and lenticular bands of limestone, and Dr. Sahni notes from these beds the occurrence of the following forms suggestive of a Lower Naungkangyi age :—

*Rafinesquina imbrex, Calymene blumenbachi, Aristocystis dagon, Orthis sp., Cyathophyllum ? sp.*

Overlying the Ordovician rocks in the same inlier are *Silurian* quartzitic sandstones of white or greenish grey colour weathering to a purplish brown. No fossils were found in these beds and their age is surmised purely from stratigraphical considerations, as they are overlain by dolomitic limestones of presumed Devonian age. The dolomitic limestones are the most extensive formation in the area surveyed and probably comprise the Devonian and

[1] *Mem. Geol. Surv. Ind.*, XXXIX, pt. 2, pp. 53-54, (1913).

Anthracolithic formations; they are everywhere unfossiliferous and their age has been based on their lithological and stratigraphical relations. Dr. Sahni believes that only the lower part of the *Plateau Limestone* formation is represented, as no normal crystalline limestones such as form the upper division of the Plateau Limestones elsewhere in the Northern Shan States were found.

The most recent rocks of the area are a series of purple sandstones and grey shales with interstratified bands of argillaceous limestone. The sandstones are invariably unfossiliferous, but the shales are occasionally and the limestones nearly always fossiliferous. Among the genera found in these beds are *Holcothyris* and *Burmirhynchia*; the beds may accordingly be correlated with the *Namyau beds* of La Touche, which, according to Buckman, are of Bathonian age. Species of *Ostrea*, *Pecten*, *Thracia*, *Cardium* and *Protocardium* are also very numerous.

Finally Dr. Sahni notes the occurrence of an extensive mass of *granite* intrusive into the Chaung Magyi series. The granite is a normal muscovite-biotite granite with orthoclase felspar and varies in texture from coarse- to very fine-grained.

**Southern Shan States.**

66. Dr. Coggin Brown and Mr. V. P. Sondhi in studying the geology of the country between Kalaw and Taunggyi in the Southern Shan States brought to light some new and interesting facts regarding Shan States geology as a whole. They found that the Lower Palæozoic succession was more complete and widespread than its homotaxial equivalent described by La Touche[1] in the Northern Shan States. The lithological characters of the rocks making up the succession were also found to be more varied, whilst some of the faunas collected were found to be not only new to the Shan States but to the whole of Asia. The Upper Plateau Limestone is also better displayed and yields more varied faunas in this area than in the north.

On the other hand some of the important rock groups of the Northern Shan States such as the Chaung Magyi series, the Namshim sandstones and the fossiliferous Namyau series are absent in the south.

In view of these important differences Dr. Coggin Brown considered it advisable to make an extended reconnaissance traverse eastwards as far as possible across the general strike of the rocks, in order to arrive at a workable classification of the rock sequence

[1] *Mem. Geol. Surv. Ind.*, XXXIX, Pt. 2, (1913).

of the Southern Shan States. Half the working season was therefore spent by Dr. Brown and Mr. Sondhi in making joint traverses from Taunggyi to the Salween, a distance of about 175 miles, and from Loilem (sheet 93 H/9) to Mawkmai (sheet 93 H/12), a distance of about 72 miles, together with a few other minor traverses. The results of their labours have been incorporated in a joint paper and will appear in due course in the *Records* of the department.

67. On the completion of the above traverses Mr. V. P. Sondhi re-surveyed a portion of sheets 93 D/10 and 93 D/14 previously carried out by the late Mr. F. W. Walker, and mapped the unfinished portion of 93 D/10, which includes the difficult country on the summit of the Shan scarp west of Kalaw, and also a portion of sheet 93 H/1 west of the longitude of Taunggyi. Revision of portions of sheet 93 D/14 were necessitated by the considerable advance in our knowledge of the various Southern Shan States limestone formations, arising from detailed mapping in the Heho area and numerous fossil discoveries during the last two field seasons. The rocks forming the Thamakan range on the west and the Heho range on the east, respectively, of the Heho plain were mapped by Mr. Walker as *Plateau Limestone;* but discoveries of Lower Palæozoic fossils in the Heho range and its northerly and southerly extensions proved it to be considerably older than the Plateau Limestone of the Thamakan range. Mr. Sondhi successfully separated the two formations where the two ranges join south of Heho, on a lithological as well as palæontological basis, and discovered three Lower Silurian graptolitic horizons and an Upper Silurian *Tentaculites* horizon near the junction.

The hill-station of Kalaw is built on a deposit of arenaceous shale, sandstones and coarse calcareous conglomerates. Except for the conglomerates, which when fresh and rich in limestone pebbles are grey, a persistent brick-red colour pervades the entire deposit, to which colour they owe their designation of '*Red Beds*'.

These beds occupy a narrow longitudinal basin on a N.N.W.-S.S.E. strike in the Loi-an series of coal measures, on which they are unconformably deposited; they are as a whole much coarser in character than is apparent from a study of the few exposures in Kalaw itself and are composed for the greater part of thick beds of conglomerate with interbedded shales and sandstones.

The western boundary of the Red Beds and *Coal Measures* follows the strike of the rocks along the crests of a system of hill

ranges, conglomerates forming the eastern portion of the hills, and light sandstones and shales of the coal measures the western flanks. The best sections of the latter rocks are seen in the railway cuttings between Sintaung and Myindaik stations and particularly between the two tunnels near the highest levels crossed by this branch of the Burma Railways.

Near the western limit of the Coal Measures three persistent beds of limestone are interbedded with shales, their northerly extension forming the western slope of the Mwedaw hill-mass where they are highly altered and mineralised by an igneous intrusion. The Coal Measures are bounded on the west by a strong well-developed hill-range of Plateau Limestone capped by the sharp, rugged and towering crags so familiar to the railway passenger between Lebyin and Sintaung; they re-appear again, however, on the west side of this limestone range.

**Shwebo district, Burma.**

68. Dr. L. A. N. Iyer on his re-transfer to Burma continued the mapping of the Shwebo district from where he left off in the field season of 1929-30. Sheet 84 M/12 and about two-thirds of sheet 84 M/16 were completed by Dr. Iyer during the course of the season. These sheets are the northern continuation of the one-inch sheets surveyed by Mr. V. P. Sondhi in degree sheet 84 N.

The following geological formations and a basic dyke cutting the Pegu series were mapped by Dr. Iyer:—

4. Alluvium.
3. Irrawadian series.
2. Pegu series.
1. Mogok series.

The *alluvium* is confined to the south-west corner of sheet 84 M/12 around the village of Methe (95° 35′ : 23° 2′) and consists for the most part of loose white sand, although occasionally a little clayey soil is encountered. It passes imperceptibly into the *Irrawadian series,* which occupies the greater part of sheets 84 M/12 and 84 M/16. The latter series consists of friable, easily weathered white or light-coloured current-bedded sandstone containing, locally, gravel and pebbles. Its surface is often covered by loose sand or small patches of clay. Fossil wood exhibiting a fibrous structure suggestive of palms occurs abundantly both as broken debris and in long trunks, the latter being well seen west of Tandaw. The sandy cover at times gives place to a coarse gravel formed of large

pebbles, overlying a coarse sandstone containing abundant fossil-wood debris, as may be seen two miles north of Inlegyi (23° 6′ : 95° 36′).

In addition to fossil wood the following fragmentary vertebrate fossils were collected by Dr. Iyer south-east of Gada (23° 13′ : 95° 39′) and S.S.W. of Tandaw :—

(1) Teeth and fragmental vertebra and limb bones of Rhinoceros.
(2) Lower molars of *Anthracotherium* cf. *silistrencis.*
(3) Crocodile teeth.
(4) A few leaf impressions and small pockets of lignite in the sandstones.

The *Pegu series* is found in two main areas, the first as an irregularly inlier in the Irrawadian series extending from west of Ngapyawdaing (23° 5′ : 95° 43′) in sheet 84 M/12 eastwards into sheet M/16 and, after describing an arc round Chaungshe (95° 52′ : 23° 4′), south-westwards to the limits of the sheet; the second area is in the range of hills running in a north-south direction on the west bank of the Irrawaddy. In the former area the dips of the rocks are low and subsidiary folding has occurred; in the latter the folding of alternating shale and sandstone bands has been more regular and high dips are common.

The Pegu rocks examined vary from a fragile clay or shale to an alternating fine-grained, bedded sandstone and clay, or to a hard fine-grained sandstone with thin bands of grey limestone. The dips vary from horizontal to vertical and the sandstones are all calcareous. In places a gradual passage was seen from the Pegu series into the Irrawadian. The limestone bands of the Pegus are grey in colour and consist of grains of quartz, chlorite and biotite in a calcareous base that forms the greater part of the rock; they pass into calcareous sandstones in which iron-ore and sericite in addition to the minerals mentioned above are also present.

The basic intrusion occurs as a long and thin dyke in the Pegu rocks of the anticline flanking the river and shows a certain amount of local variation. It is composed of a fine to medium-grained hemi-crystalline rock intermediate in composition between andesite and dolerite. Felspar (andesine to labradorite) occurs both as phenocrysts and as microlites; a green interstitial pyroxene is mostly altered to serpentine, as also is the olivine which is sometimes found ; magnetite occurs in small grains.

A small exposure of the *Mogok series* occurs in the south-east corner of sheet 84 M/16, half a mile south-west by south of Male (23° 2′ : 95° 49′). The rocks exposed form a complex of predominant blue-grey dolomitised limestones forming massive ridges, with acid gneiss and highly banded hornblende-schist: the rocks dip at high angles to the east and west. This complex is separated from the Pegu rocks to the west by a north-south strike fault.

**Northern Circle.**

69. During the field season 1931-32 the officers working in the Northern Circle were Dr. A. M. Heron (in charge), Messrs. E. R. Gee (Punjab) and Mr. J. B. Auden (Punjab), Dr. P. K. Ghose (Rajputana and Bombay), Messrs. H. M. Lahiri (Punjab), B. C. Gupta (Bombay and Central India) and A. M. N. Ghosh (Punjab). Mr. D. N. Wadia, who was at headquarters as Palæontologist during the year, has submitted some notes on the examination of specimens collected in Kashmir in the previous year, which are referred to below.

**Kashmir.**

70. The study of the rocks and fossil collections made by Mr. D. N. Wadia in the Burzil valley, Kashmir, in 1931, during his traverse to Gilgit, has led to some interesting results and, at the same time, emphasised the desirability of a detailed survey of this ground when the new topographical sheets of the area, on the one-inch scale, become available, the existing maps being on the scale of quarter-inch to the mile. A few imperfect fossils obtained from the grey-blue limestone, exposed in the towering crags and precipices of Gurais, are identical with those found in the Upper Trias of S. E. Kashmir. The fossils are too badly preserved for specific identification, but the following genera can be made out with some certainty: *Myophoria*, *Trigonia* sp., two species of *Dielasma* (aff. *D. julicum*, Bittner and *D. himalayanum*, Bittner), *Marmolatella*, one or two species of the large, thick-valved *Megalodon*, and some corals and crinoids. The Upper Trias of Kashmir, unlike that of Spiti, is rather poorly fossiliferous and, for the most part, is totally lacking in the large cephalopod fauna that characterises the underlying Muschelkalk. It is possible that a semi-crystalline crinoidal limestone, occurring at the base of the limestone of Gurais contains some Upper Zewan beds, but as the characteristic lower *Protoretepora ampla* zone is absent, one cannot be certain of this.

Two miles below Minimarg (34° 48′ : 75° 5′), on the road to the Burzil pass, rocks belonging to the lower part of the Zewan series

occur in small patches overlying the Agglomeratic Slates associated with an outcrop of the Panjal volcanic series five miles wide. The outcrop of the latter series stretches across the mountains for many miles in a N.W.-S.E. direction, that is parallel to the general trend of the Great Himalaya Range. These Zewan beds comprise a slabby limestone with well-formed zoaria of *Protoretepora ampla* and of *Acanthocladia* succeeded by ash beds and tuffs interstratified with amygdaloidal basaltic lavas. The higher more massive beds of limestone of the Zewan series are not developed. Some of the Agglomeratic Slates in their lithology recall the Eurydesma stage of Bren near Srinagar, though Mr. Wadia did not find any typical fossils, but only broken shell-valves and carbonised plant-tissue.

In the previous General Report certain foraminiferal limestones found some 12 miles south-east of the Burzil pass were regarded as Eocene in age, and as probably a western outlier of the Nummulitics of Dras in Ladakh. Two specimens of this limestone have, however, since been found to contain the Upper Cretaceous foraminifer *Orbitolina.* In 1906, Sir Henry Hayden brought specimens of this limestone from a locality much higher up the same valley, described as 'east side of Dorikum (Burzil) pass, 500 feet above the pass'. The genus *Orbitolina* was identified in Hayden's specimens by Prof. Douville.[1] Although no identifiable Tertiary fossils have been found at this Burzil locality, yet Mr. Wadia is of opinion that the major portion of the rocks here is of Nummulitic age; for they are bituminous limestones, strongly veined with calcite, and markedly similar in general lithological aspect to the Nummulitic limestone of the Margala Hills and of the south-west flank of the Pir Panjal.

**Attock and Mianwali districts, Punjab.**

71. During the early part of the field season Mr. H. M. Lahiri continued his previous mapping on to sheets 38 P/13 and 38 P/14, which lie partly in the Mianwali and partly in the Attock districts.

The geological formations met with in the area are the same as those in sheet 43 D/2, namely Laki to Middle Siwalik with alluvium (*see* previous General Report, p. 120). The sandy beds of the upper part of the Kamlial-Murree succession are, however, less compact in the present area, so that they are not seen to form prominent strike ridges as in the sheet mentioned. All the boundaries, except that between the Nagris and the Dhok Pathans are fairly well defined.

[1] *Rec. Geol. Surv. Ind.*, LVIII, p. 349, (1926).

The Siwalik strata are here only sparingly fossiliferous, the identifiable fossils collected being some isolated equine teeth from the Dhok Pathan beds, which have been provisionally identified as *Hipparion punjabense* Lyd., and *H. theobaldi* Lyd.

The beds examined occur on the southern limb of the great Soan syncline, the various formations being normally superposed on one another. The strike is E.N.E.–W.S.W. in the north-eastern quadrant of 38 P/14, but it swings round to the N.N.W.–S.S.E. near Nammal (32° 40′ : 71° 48′), and maintains that direction further to the north and west. Dips vary from 5° to 50° degrees, the higher dips being confined to the lower beds.

**Salt Range, Punjab.**

72. From December 1931 till May 1932, Mr. E. R. Gee continued fieldwork in the Salt Range. The area mapped included the southern edge of sheet 43 D/9 in the vicinity of Kallar Kahar (32° 47′ : 72° 41′ 30″), the north-western portion of 43 D/10 including the Vasnal (32° 43′ : 72° 33′) and Munarah (32° 40′ : 72° 31′) plateaus, the scarp and plateau areas of 43 D/6 and D/7 lying north of Katha (32° 31′ : 72° 26′) and Nali (32° 29′ : 72° 20′), 43 D/3 as far west as Jabbi (32° 24′ : 72° 6′) and Jalhar (32° 6′ : 72° 15′); fieldwork was also continued into the southern part of 43 D/2, to the west of Khura (32° 32′ : 72° 13′). During the latter half of May, 1932, Mr. Gee proceeded to Khewra (32° 39′ : 73° 0′) and, with a view to advising the authorities of the Northern India Salt Revenue Department regarding the probable extension of the seams of rock-salt to the east of the present mine-workings, he carried out an examination of the Mayo Salt Mine (*see* page 39).

During the course of the examination of the *Salt Marl* within the above-mentioned areas, further evidence accrued regarding the age of this series. In the Kalra Wahan, about 1¾ miles south of Changeanwali (32° 36′ 30″ : 72° 27′ 30″), bands of somewhat-foliated red clay-shale, steeply-dipping, and intercalated within the salt-bearing marl, were found to include numerous small, carbonised plant fragments and a few small leaves. A few plant fragments were also found in thin bands of clay interbedded among the seams of rocksalt which crop out in the Warik Nadi, to the west of Nali. Again, in a band of hard, dull red clay interbanded with the marl and impure rocksalt that occurs between the Sujowal and Buggy seams of the north-eastern end of the Mayo Salt Mine, Khewra, carbonised plant fragments were discovered. These plant fossils,

although throwing no light on the exact horizon of the Salt Marl at least favour the Tertiary age so strongly indicated by the Ranikot foraminifera discovered during the field-season 1929-30.[1]

The principal changes in the stratigraphical sequence noticed as the area examined is traversed from east to west (*i.e.*, from Katha to Jabbi) are as follows :—

1. The *Neobolus Shales* die out in the vicinity of Katha, the overlying Talchir boulder-bed resting directly on the Purple Sandstones.

2. The *Productus Limestones* thicken very considerably to the west. North-east of Katha, in the vicinity of Pail (32° 38′ : 72° 28′), this series includes only the Lower Productus strata. To the south, in the Kalra Wahan, higher beds come in—the Middle Productus or 'Cliff' Limestones—and these attain a thickness of 250 to 300 feet in the vicinity of Nali and further west. To the north of Mohra (32° 26′ : 72° 17′) softer, fossiliferous, green sandstones and impure limestones are included above the Middle Productus Limestones; these—the Upper Productus beds—attain a thickness of about 150 to 200 feet to the north of Jabbi.

3. *Ceratite-bearing shales* (Triassic) intervene between the Upper Productus beds and the basal Nummulitics to the north of Kund (32° 25′ : 72° 13′). These beds include greenish-yellow and brownish-grey flaggy limestones and olive-green shales, about 50 feet thick to the north of Jalhar.

The remaining strata—Salt Marl, Purple Sandstones, Speckled Sandstones, Nummulitics and Siwaliks—remain fairly constant and are similar to the exposures of the more eastern parts of the Salt Range. One point of importance in connection with the *Speckled Sandstone series* was the discovery of Lower Gondwana plant fossils, including *Glossopteris* and other forms, near the base of this series, in the area north of Kund (*see* page 22).

In the upland valleys in which the villages of Kalial (32° 33′ : 72° 18′), Triri (32° 32′ : 72° 16′), and Kandana (32° 32′ : 72° 18′) are situated, a series of massive, fairly soft, dull green and brown sandstones, with some grey clay bands and orange-brown clays above, intervenes between the alluvium and the Hill Limestones. Though resembling in lithology the Lower Siwalik sandstones, these

[1] *Rec. Geol. Surv. Ind.*, LXIII, p. 25, (1930); LXVI, pp 32, 117, (1932).

beds include none of the red clays of that series. At the base is often a bed composed of irregular blocks of sandstone of Kamlial type and of silicified fossil wood ( ? derived). The grey clay bands include some lignified wood and numerous fish scales, etc. Though probably decidedly younger than the underlying Hill Limestones these strata have been incorporated in the folding which affected the underlying Nummulitics. Mr. Gee has temporarily designated these strata the *Kandana beds*.

The *tectonics* of the area under description are, like those of the more eastern tracts already examined by Mr. Gee, very complex. Excluding the question of the disturbance separating the Salt Marl and Purple Sandstone beds—along which definite evidence of brecciation is often observed—, Mr. Gee notes that portions of the Salt Marl and the Purple Sandstone series are often repeated by overthrusting. This is particularly well seen in the vicinity of the exit of the Dilliwali gorge to the north of Nali, and again north of Kund and Sikriala (32° 24′ : 72° 10′). Overthrusting and shearing within the higher strata is also prominent; in a number of instances, the softer strata--particularly the soft clays of the Speckled Sandstone series--have been squeezed out at least at their outcrops. Normal faulting was also a prominent feature in parts of the plateau. Mr. Gee notes that the main gorges which intersect the scarp and the plateau have been eroded either along the axes of anticlinal folds or along lines of faulting. He notes that there are two principal lines of folding or fold-faulting, one roughly E. W. parallel to the scarp, and the other at right angles, the latter being probably slightly the later. The E.-W. folds and thrusts appear, however, to be of fairly recent—very late Tertiary or Pleistocene—age, for at several places at the foot of the scarp the older beds are thrust up on to inclined boulder alluvium, whilst on the plateau to the north of Jalhar a zone of alluvium (including boulders of Nummulitic Limestone), resting on Kamlial beds unconformably, is incorporated in the E.-W. fold-faults that traverse the area.

Mr. Gee notes that the inlier of *Salt Marl* at Vasnal represents an *intrusion* of the latter as an incipient plug along a line of well-marked faulting. Similar, smaller intrusions were observed near Kallar Kahar, and again near Bhadrar (32° 39′ : 72° 30′). Along the north-west side of the ridge near the village of Pail, the Productus Limestones are thrust over the Kamlial strata which constitute the Pail-Kuchra (32° 40′ : 72° 27′) plateau.

To the south-west, in the vicinity of Katha, the Kalra Wahau coincides with a sheared N.–S. anticline. The Narshinghphoar gorge, on the other hand, is more complex. Overthrusting has occurred in the lower part of the gorge not far from its exit, the middle portion of the gorge coincides with a faulted anticline, whilst in the upper reaches near Shahalanwali (32° 35′ : 72° 22′) definite overfolding of the Productus beds has occurred in the southern slopes.

The Dilliwali gorge is again eroded along the line of a faulted anticline, whilst further west, the Lunwala ravine follows the trend of an E.–W. fold-fault. Similar N.-S. and E.–W. folds, often accompanied by overthrusting, are well-marked in the gorge sections north of Kund, Chenki (32° 23′ : 72° 7′) and Jabbi. The structure of the Kohad gorge north of the latter village (32° 25′ 30″ : 72° 7′ 30″) is very complex, the Salt Marl recurring along faulted anticlines in the intersected plateau area about 5 to 6 miles from the gorge exit.

The plateau tracts to the north of Katha include outcrops of the Hill Limestones capped by Kamlials and by alluvium, the structure being relatively simple. Further west, to the north of Nali, Kund and Jabbi, the hard Middle Productus Limestones cover wide areas often badly faulted; but to the north, in the Surakki (32° 31′ 30″ : 72° 8′)- Sodhi (32° 35′ : 72° 16′) area the Hill Limestones are again prominent as a number of anticlinal, often faulted, E.-W. ridges alternating with alluvial, synclinal valleys.

To the south of the Salt Range, the usual boulder-fans followed by sandy alluvium beyond are met with.

73. During January and February Mr. Austin M. N. Ghosh accompanied Mr. Gee for instructions in Salt Range stratigraphy. After this, for the remainder of the field season, a period of some two and a half months, Mr. Ghosh's services were placed at the disposal of Dr. Hellmut de Terra of Yale University, and he was requested to make collections of fossils from the Productus Limestone, and the Triassic limestone and marl beds of the Salt Range. Mr. Ghosh visited Chideru (32° 32′ : 71° 46′), Amb (32° 30′ : 71° 55′), and Warcha Mandi (32° 25′ : 71° 58′) in this connection. A fairly representative collection of fossils was made from the lower, middle, and upper divisions of the Productus Limestones at the three localities visited. The Ceratite beds at Chideru and Amb yielded a fair number of ammonites. The fossils collected were sent to Prof. Charles Schuchert at the Peabody Museum of Yale University. Mr.

Ghosh has submitted a well-written Progress Report on the work done when he was with Mr. Gee; in addition, his activities as a collector for the Yale University Expedition have earned high praise from Professor Schuchert.

**Hoshiarpur and Kangra districts, and Bilaspur State, Punjab.**

74. In the latter part of the field season Mr. Lahiri mapped parts of sheets 53 A/6, 53 A/7, and 53 A/N.E., which include portions of the Hoshiarpur and Kangra districts, and of the Bilaspur State. The country mapped forms part of the Sub-Himalaya and consists of a series of low parallel hill ranges stretching N.W.–S.E. and separated by wide valleys. The most prominent among these is the Solasinghi or Chaumukhi ridge, the highest peak of which (Solasinghi) attains an altitude of 3,812 feet in sheet 53 A/6.

The area surveyed is included in H. B. Medlicott's small-scale geological map of the Sub-Himalayan country between the Ganges and the Ravi[1] and is shown mainly as Siwaliks without subdivisions. Mr. Lahiri has followed Dr. Pilgrim's unpublished maps of the adjoining country in which several stratigraphical divisions are represented.

The geological formations met with are the Kasaulis of the Sirmur series, the Nahans or Lower Siwaliks, and the Middle and Upper Siwaliks (including the Pinjor and Boulder Conglomerate stages) as recognised by Dr. Pilgrim.

Vertebrate fossils are rare. The few specimens obtained include *Hipparion theobaldi* Lyd. from the Middle Siwaliks, and *Hippopotamus sivalensis* Falc. and Caut. and a fragmentary tooth of *Elephas* from the upper strata of the Pinjors. Fossil wood partly altered into limonite was occasionally met with in the Middle Siwaliks.

Folds and faults with axes running N.W.–S.E. are the chief structural feature of the country. The compression has been most intense along the Solasinghi ridge, where the structure is that of a highly squeezed anticline in Middle and Lower Siwalik strata and underlying Kasaulis broken by a prominent strike fault (the Budsur fault of Medlicott), which runs along the north-eastern foot of the ridge over the whole of the area examined. The crest of the ridge is formed of Lower Siwalik or Nahan sandstone. North-eastwards from this fault the main structure is that of a syncline of Pinjor rocks also broken by a strike fault, which is traceable in a N.N.W.–S.S.E. direction for at least ten miles. Further to the north-east

[1] *Mem. Geol. Surv. Ind.*, III, Pt. II, (1864).

Middle Siwalik beds are seen overthrust on to Pinjor strata along a fault line (the Gumber fault of Medlicott), which unlike the other faults in the area follows a markedly zig-zag course.

To the south-west of the Solasinghi ridge almost vertical Pinjor beds are seen faulted against the lower strata of the Middle Siwaliks in the Lunkhar valley. South-westward from this fault (the Kesori fault of Medlicott) the structure is first that of a syncline of Middle Siwalik beds with an outlier of Pinjors. This is followed on the south-west by an asymmetric anticline, which is in the same tectonic line with the Naina Devi flexure.

The dips of the various beds vary from 5 degrees to vertical, and are mostly either north-easterly or south-westerly.

**Simla Hills; Sutlej valley, Punjab.**

75. Between January 15th and February 21st, Mr. Auden traversed from Subathu, along the Gambhar river, to Bilaspur and Bakhra, on the Sutlej river, over Tertiary rocks which had been previously mapped by Dr. Pilgrim (degree sheet 53 A). A narrow outcrop of limestone occurs among these Tertiaries as far as Bilaspur. This proves to be Krol limestone, as had been suspected by Medlicott and Pilgrim. In numerous localities the Tertiaries appear to dip under the Krols on both sides of their outcrop. This is particularly well seen at Bilaspur, and near Badhota (31° 03′ : 76° 55′). In the short time available Mr. Auden did not consider that sufficient evidence was obtained to prove whether the Krols occurred as a nappe truly above the Tertiaries, or whether the inward dips were to be explained by extensive mushroom folding.

**Simla Hills; Chakrata district, United Provinces.**

76. During a period of some three months from the end of February Mr. Auden continued his survey of the belt of Krol rocks south-east of Simla, working in sheets 53 F/6, 10, 14. In July four days were spent at Lachmanjhula (53 J/S. W.) and in October traverses were made in the neighbourhood of Mussoorie (53 J/3) and Lansdowne (53 K/N.E.). Mr. Auden is confident that some of the rocks of the Krol Belt may be correlated with those mapped by Middlemiss in Garhwal.[1] The rocks which, west of the Tons river, he had tentatively correlated with the Tals of Garhwal (General Report for 1931, p. 126), he now considers definitely to be their equivalent. Another complete synclinal basin of these beds has been found in the eastern part of sheet 53 F/10, north of the

[1] *Rec. Geol. Surv. Ind.*, XX, p. 33, (1887).

Giri river. Tal beds are also seen, again synclinally disposed on Krols, from Landour, near Mussoorie, to Masrani (30° 27′ : 78° 09′), on the Tehri road. The 'Massive Limestone' of Garhwal corresponds to the Upper Krol limestone of the Solon area, and to the limestones of the Mussoorie ridge. North-east of Lansdowne, in the Medi Gad near Raitpur (29° 54′ : 78° 42′) the 'Purple Slate' division of Middlemiss was found to be composite, being made up of Krol B (Red Shales), Krol A (Lower Krol limestone), and Infra-Krol, all of which are recognisable, and probably attenuated Jaunsars. The most significant change in the Krol limestones, from the point of view of correlations, is the increasingly slaty character of the Krol A sub-stage to the south-east. While near Solon this sub-stage is made up of well-bedded limestones, clearly belonging to the Krol limestone division, to the south-east it becomes less calcareous and more cleaved, until in Garhwal, together with the Krol Red Shales, it should properly be mapped, as Middlemiss has done, with the underlying slaty series. On the correlation of the Upper Krol limestones with the Massive Limestone, these beds are seen to extend from Bilaspur (31° 20′ : 76° 45′) to Ghungti Hill (29° 45′ : 78° 55′), a distance of some 175 miles. Below is the suggested correlation.

| *Simla Hills.* | *Garhwal.* |
|---|---|
| Upper Tals . . . . . . . | Tal limestones.<br>Tal quartzites. |
| Lower Tals . . . . . . . | Almost absent. |
| Krol E<br>Krol D (Upper Krol limestone)<br>Krol C . | Massive Limestone. |
| Krol B (Red Shales) . . . . | Purple Slates. |
| Krol A (Lower Krol limestone) | |
| Infra-Krol | |
| Blaini . . . . . . . | (Thin conglomeratic boulder bed seen in Purple slates in Medi Gad). |
| Jaunsars | |
| Mandhalis ? . . . . . . . | Volcanic breccia. |

In the area mapped in detail, Mr. Auden has followed the Krol thrust eastwards to the Jumna river. Near Dadahu (30° 36′ : 77° 26′) the thrust brings Krols, Infra-Krols, Blaini and Jaunsars on to Subathus, which are locally phyllitised so as to be hardly recognisable.[1] Eastwards, in the Tons, Amlawa and Jumna rivers, the older rocks are brought at low angles of 20° to 30° directly on the Nahans, with doubtful Dagshais. Since at Bilaspur Krols were seen to rest at 35° on Upper Siwalik conglomerates, it is evident that the final movements along this thrust plane were as late as Pliocene in age.

Dolerites, rich in sodic plagioclase and often with marked intergrowth of felspar and quartz, have been found along the Giri river east of Dadahu, intrusive into Subathus and Nahans. They are properly 'greenstones' with augite converted extensively to uralite and chlorite and with strongly saussuritised felspars. These intrusions must be of Miocene or later age.

With regard to the succession in the Tons area, Mr. Auden states that the descending sequence of Tals, Krols, Blaini and Jaunsars is normal. At the base of the Jaunsars, however, occur boulder beds very similar to those in the Blaini, associated with conglomerates, quartzites, limestones phyllites and bleaching slates. These beds were mapped by Oldham in 1883[2] as 'Mandhali', and are found dipping synclinally below the Jaunsars, northwards at Kalsi (30° 32′ : 77° 51′), and southwards at Nasaya (30° 40′ : 77° 50′). Individual facies in these Mandhalis show striking resemblance to the Krols, Infra-Krols, Blainis and Jaunsars. If they are a development of the Blaini, it follows that the whole Tal-Jaunsar sequence rests as a synclinal nappe-outlier on the Blaini, which are younger than Jaunsars, and that this complex of nappe-outlier and underlying Blainis (Mandhali) has been brought forward by the Krol thrust over Nahans. Mr. Auden is not convinced that the correlation of the Mandhalis with the Blainis is proved solely on the resemblance between the boulder beds in the two formations, though he admits that to the east of sheet 53 F/10 it is difficult to distinguish between the two. A further difficulty is found in the impossibility of accurately separating the Mandhalis from the Jaunsars, to which series they bear on the whole greater resemblance than they do to the Blainis.

[1] Compare *Mem. Geol. Surv. Ind.*, XXIV, p. 72, (1890).
[2] *Rec. Geol. Surv. Ind.*, XVI, p. 193, (1883).

On the north side of the Tal-Jaunsar syncline, the Mandhalis appear to be thrust over a series of purple slates, purple and white sandstones and quartzites, which are seen along the Tons river near Morar (30° 40′ : 77° 46′) and at Chakrata. These beds were mapped by Oldham as the same series as the Jaunsars, but Mr. Auden considers them to be different, and possibly to be equivalent to the Simla slates.

**Jodhpur State, Rajputana.**

77. During the earlier part of the season Dr. P. K. Ghosh completed the survey of the S. W. part of Marwar (Jodhpur State) in Rajputana, on standard sheets C. I. and Raj. 74, 75 and 76: during the latter part of the season he surveyed the greater portion of Palanpur State, working on standard sheets, C. I. and Raj. 76 and 77 and Bombay 117 and 118. The rocks of both these areas belong to the Delhi system.

In the S. W. of Marwar, there is an extensive development of igneous rocks which had previously been mapped by Hacket as gneiss. During the present survey this gneiss has been shown to be composite and to consist of successive intrusions of the Erinpura granite and its pegmatite, of the Jalor granite and its differentiates (microgranite, granite-porphyry, aplite and quartz-porphyry), and of minor basic rocks belonging to at least three different horizons.

The *Erinpura granite* is marked by a lack of differentiated products except pegmatite, while the *Jalor granite* is very rich in this respect. The granite-porphyries associated with the Jalor granite are divisible into two types, namely (1) a highly potassic type, occurring chiefly as N.N.W.-S.S.E. dykes and (2) a more sodi-calcic type, occurring only in lenticular masses (probably as sills). Both these types are fairly rich in fluorite. Lepidolite has been found in type (2). The quartz-porphyries occur only as dykes with a N.N.E.-S.S.W. trend, and are definitely later than the granite-porphyries, which they cut in one place. They are also highly potassic and fairly rich in fluorite, and are thus allied to the type (1) of the granite-porphyries.

In the western part of sheet 76 there is an outcrop of *Malani rhyolite* associated with many bedded tuffs. These rocks are little disturbed and are therefore thought to be younger than the Erinpura granite. They may be the volcanic equivalents of the Jalor granite and its differentiates.

The acid intrusives of the region are mixed with basic rocks, small outcrops of which occur throughout the area. They have been classified as follows :—

(1) *Amphibolites and schistose epidiorites.*—These are the oldest igneous rocks, and occur intercalated with the sedimentary series, and as inclusions in the granites. No trace of augite remains.

(2) *Coarse dolerites and gabbros.*—The stratigraphical horizon of this group is not clearly established. It is certainly younger than the Erinpura granite, and possibly older than the Jalor. Augite, though in course of alteration to amphibolite, is rarely absent.

(3) *Fine-grained dolerite and basalt.*—These are the youngest igneous rocks of the area, and occur chiefly as thin veins intersecting all other rocks. They show little signs of pressure metamorphism. Some of these dykes contain porphyritic crystals of basic plagioclase up to 2 inches in length. Others show abundant porphyritic biotite which gives them a lamprophyric character. Others again are typical dolerites, with titan-augite.

**Palanpur State, Bombay.**

78. The geology of the Palanpur state is a continuation of that of Marwar. The chief points of difference are as follows :—

Among the sedimentaries the phyllites and calcareous rocks are better developed and the quartzite is missing. In the igneous group the Jalor granite dwindles into insignificance, and the Erinpura granite takes its place. The Jalor differentiates are represented by slender veins of flesh red pegmatite, and massive quartz veins, neither of which types occurs in Marwar. The three groups of basic rocks were all recognised, but group (2) has attained a much greater development. In addition, in the north-west corner of sheet 77, there are a number of narrow dykes coloured in various shades from mauve to black, and with an east-west strike. These rocks, which are almost entirely composed of oligoclase, are doubtfully classified with group (3) of the basic rocks.

A zone of severe crushing, faulting, and secondary silicification extending over more than 15 miles in a N.E.–S.W. direction occurs in the Banas valley. It seems that the original rocks of this zone, phyllite, granite, and pegmatite, were subjected to a compressive stress in a N.W.–S.E. direction, and that relief from this was finally obtained by faulting. On the relief of pressure the silicification took place. These disturbances are perhaps representative of the earth movements that signalised the close of the Delhi period.

79. Mr. B. C. Gupta did not resume field work until February, remaining in the field until the end of April 1932. During this period he worked on standard sheets C. I. and Raj. 178, 179 and 180, the area surveyed comprising the eastern *talukas*, Jhalod and Dohad, of the Panch Mahals district of the Bombay Presidency, with adjoining strips of Kushalgarh and Jhabua States, Central India.

**Panch Mahals district, Bombay, and Jhabua States, Central India.**

The oldest group of rocks in the area is a highly *metamorphic series* consisting principally of an extensive development of slaty, phyllitic and micaceous schistose formations, with quartzites and impure calcareous rocks. These rocks have a general northerly, or north-north-westerly strike, and are continuous with the Aravalli formations as mapped further north in Rajputana. The prevailing argillaceous types of rock vary from compact grey, slaty and phyllitic forms in the area north of Dohad to a more highly metamorphosed greyish white micaceous schists spotted with specks of biotite and sericite further south.

Lying unconformably on these Archaean metamorphics are several patches of a massive, impure, unfossiliferous limestone, which, on account of its lithological characteristics and infra-trappean position, must be correlated with the Bagh beds of Central India and the Lametas of the Central Provinces.

Characteristically variable as is this *Lameta limestone*, it makes a more or less definite and sharp contact with the underlying Aravallis. In the Chhindwara district, Central Provinces, there is abundant evidence[1] of the formation of such limestones by the metasomatic replacement of the underlying rocks. No such evidence has been found by Mr. Gupta in the area under review.

Underlying the Lametas, and often resting directly on the Aravallis occur basalitic lava flows of the *Deccan trap* series. These lavas are characterised by a general homogeneity of composition, by compactness of texture, and by fineness of grain. Porphyritic types are rare, and vesicular or amygdaloidal forms were not recorded in the field.

No Tertiary formations were observed in the area surveyed.

80. During the field season 1931-32 the officers working in the Southern Circle were Dr. C. S. Fox (in charge; Central Provinces), Mr. A. L. Coulson (Madras), Dr. M. S. Krishnan (Bihar and Orissa), Mr. D. Bhattacharji

**Southern Circle.**

[1] L. L. Fermor and C. S. Fox, *Rec. Geol. Surv. Ind.*, XLIII, pp. 32-33, (1913).

(Central Provinces) and Mr. P. N. Mukherjee (Madras). In addition Mr. H. Cecil Jones, who was at Headquarters writing his report on the iron-ore deposits of Bihar and Orissa, made a brief visit in January to some of the iron-ore mines of Singhbhum in order to bring his knowledge up to date.

**Bihar and Orissa.**

**Gangpur, Bonai, and Bamra States.**

81. During the field season 1931-1932, the only officer available for field work in Bihar and Orissa was Dr. M. S. Krishnan, who continued his systematic mapping of Gangpur State and adjoining areas. The maps used were on the scale of two miles to the inch, and the area mapped, which is about 450 square miles in extent, covers the greater part of the southern half of sheet 73 B/S.E., comprising parts of Gangpur and Bonai States and the part of sheet 73 B/S.W. lying within the borders of Bamra State.

The country is hilly and contains some prominent ranges of quartzites and micaceous quartz-schists near the southern margin, where they rise to an altitude of about 2,500 feet. The rocks met with comprise mica-schists, micaceous quartz-schists, quartzites and carbonaceous phyllites, with epidiorite sills and some irregular exposures of granite-gneiss and granite. Veins of quartz and pegmatite are common.

A synclinal structure can be made out along the middle of the area, its axis having an approximate E. N. E.-W. S. W. trend. The feature that separates this from the Gangpur anticlinorium is the horizon of sheared conglomerate which extends nearly parallel to, and one to three miles north of, the Bengal Nagpur Railway track from Jaraikela (22° 19′ : 85° 7′) to Bamra (22° 3′ : 84° 17′ 30″). This horizon, which may be called the 'Raghunathpali conglomerate' marks, according to Dr. Krishnan, a zone of shearing.

To the south and south-east of the present area there are phyllites, sandstones, quartzites, banded haematite-jasper, etc., in which there are no rocks directly comparable with the gondites and the marbles of the Gangpur anticlinorium. The strata in south-west Singhbhum have dips towards the north-west or N. N. W., conformable with those in the present area. There is undoubtedly much close isoclinal folding throughout the area, bringing about a repetition of the beds; but it seems clear that as we proceed south-eastwards from the sheared conglomerate horizon in Gangpur into South Singhbhum

we come into older beds, of which the oldest belong to the basal portions of the Iron-ore series.

The series of rocks exposed in the Gangpur anticlinorium and to which Dr. Krishnan proposes for local use the name *Gangpur series*, is regarded by him as older than the Iron-ore series. The two series are separated by the Raghunathpali conglomerate. The beds exposed in South-east Gangpur and the adjoining parts of Bonai will form the upper parts of the Iron-ore series which have been brought into juxtaposition with the Gangpur series by vertical movement, which may be of the nature of a slide.

On this interpretation the rocks occurring in Gangpur State may therefore be arranged stratigraphically as shown below:—

| | |
|---|---|
| | Granite |
| Iron-ore series. | Epidiorite with local tuffs (Dalma trap ?). |
| | Mica-schists and carbon-phyllites. |
| | Quartzites and conglomerates. |
| | Mica-schists and phyllites. |
| | (Lower parts of the Iron-ore series—unrepresented here). |
| | ——————(Slide). |
| Gangpur series. | Sheared conglomerate (Raghunathpali conglomerate). |
| | Mica-schists with two horizons of carbon-phyllite. |
| | Dolomitic and calcitic marbles. |
| | Mica-schists and phyllites with intercalations of gondite. |

The presence of carbon-phyllites in each series is of interest, and if one recalls that the basal portions of the shales in the Iron-ore series in South Singhbhum contain manganiferous and calcareous bands, one might be tempted to suggest that the two series are one and the same. Apart from the fact, however, that it is not impossible for there to have been more than one period when manganiferous sediments were deposited, it may be recalled that on examining the manganese-ore occurrences of Chaibasa many years ago before the possible stratigraphical importance of the point was evident, I came to the conclusion [1] that the bed-like layers of manganese-ore of that neighbourhood were due to the surface replacement of the associated slates and phyllites. Dr. Krishnan appears, therefore, to be entitled to regard the two series as of different ages, as shown in the above table.

Judging from the presence of gonditic rocks, as well as of the overlying marbles, it must be accepted that the Gangpur series is equivalent to a portion of the Sausar series, and this correlation agrees with the fact that the Gangpur anticlinorium is on the general

[1] *Mem. Geol. Surv. Ind.*, XXXVII, p. 620, (1909).

strike of the Sausar belt of the Central Provinces. This separation of the schistose and phyllitic rocks of Gangpur, Bonai and Singhbhum into a more northern belt (Gangpur series) with marbles and gonditic rocks, and a more southern belt (Iron-ore series) is closely parallel to the separation of the schistose and phyllitic rocks of the Nagpur and Bhandara districts of the Central Provinces into a northern belt (the Sausar series) with marbles and gondites and a more southern belt (the Sakoli series) devoid of such rocks [1].

Phyllites and mica-schists are the most abundant rocks of the region. They usually contain quartz, biotite, muscovite and a little chlorite. Locally they become garnetiferous. A zone of garnet-staurolite-mica-schists occurs just to the north of a large epidiorite sill extending from Gailo (22° 4′ : 84° 44′ 30″) to Rabga (22° 4′ 30″ : 84° 28′). Lenticular masses of chlorite-schists are occasionally found amidst the mica-schists. The mica-schists are also found to be sometimes felspathic, owing perhaps to the addition of granitic material.

Near the southern margin of the area there are large hills composed of micaceous quartz-schists, quartzites and conglomerates. The last form irregular and impersistent bands and generally show evidence of crushing and shearing.

Some conspicuous bands of carbonaceous phyllite are found in the south central portions. Just to the west of the valley of the Brahmani river, they show a marked bend in their strike, from W. S. W. to W. N. W., at longitude 84° 50′. A thin bed of the same rock, which is associated with the epidiorite sill mentioned above, shows the effect of shattering, and is partly replaced by, and veined with, secondary quartz.

There are several sills and some lenticular masses of epidiorite in the area. They all probably belong to the same magmatic source as gave rise to the Dalma traps. The original basic igneous rock has been altered to amphibole-schist, consisting chiefly of an amphibole near actinolite in characters, and varying amounts of albitised felspars, epidote, clinozoisite and small quantities of calcite, chlorite, magnetite, and ilmenite. The large epidiorite sill mentioned above shows also a small area of tremolite-dolomite-phlogopite-schist at its south-eastern end.

Two bands consisting of a dark greenish-grey, conglomeratic schist occur in the south-eastern corner of sheet 73B/S. E., one

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 132, (1930).

extending from Nawagaon (22° 5′: 85° 0′) to Silpungi (22° 2′: 84° 56′) and the other near Thiatangar (22° 0′: 84° 55′). The rock shows much chlorite and quartz and smaller amounts of magnetite and occasional felspar. The pebbles are of granular quartzite and jasper, the latter showing quartz, magnetite (martite), and dolomite rhombs. Occasional biotite and epidote are also found in the groundmass. Dr. Krishnan suggests that this rock may be a metamorphosed tuff containing pebbles of sedimentary origin.

Several patches of granite-gneiss occur in the area to the east and north of Jara (22° 1′: 84° 39′). This seems to be older than the unfoliated intrusive granite found in the extreme south-eastern corner of sheet 73B/S. E. The pegmatite and quartz veins penetrating the schists in many places are to be assigned to the latter.

**Central Provinces.**

**Betul and Chhindwara districts.**

82. The officers working in the Central Provinces were Dr. C. S. Fox and Mr. D. Bhattacharjee. Dr. C. S. Fox devoted the whole field season, from December, 1931, to April, 1932, to rounding off surveys in the Chhindwara, Betul and Hoshangabad Districts of the Central Provinces in the Satpura region.

He has now completed the examination and mapping of practically the whole area comprised in the map accompanying Mr. E. J. Jones' memoir (Vol. 24) on 'The Southern Coal-fields of the Sátpura Gondwána Basin'. These are included in sheets (1 inch to the mile) 55F/11, 55F/15, 55F/16, 55J/3, 55J/4, 55J/7, 55J/8, 55J/11, 55J/12 55J/15, and 55J/16. With the completion of these sheets and those mapped by Mr. H. Crookshank along the northern margin of the Satpura region and including the Pachmarhi Hills, almost the whole of the Satpura region has now been mapped anew.

In carrying out this mapping Dr. Fox has been able to confirm the opinion of Mr. H. B. Medlicott that the Talchirs pass up quite conformably into the Barakars. In the area of the Suki river north of Shahpur (22° 12′: 77° 54′) it is difficult to fix a horizon that would satisfy everyone as the dividing plane between the two formations. In the Sonada field near Kuppa (22° 14′: 77° 46′) plant fossils occur in rocks of a Talchir facies.

Similarly the Barakars pass upwards into the barren measures to which Mr. Medlicott applied the term *Motur horizon.* Dr. Fox visited Motur and found that the sandstone and buff clays that occur in the small inlier in the Deccan Trap country about a mile east of Motur village (22° 17′: 78° 33′) are similar to those of the

Tawa valley and unlike the descriptions given by E. J. Jones[1] of the Moturs of the Pench Valley. For this reason Dr. Fox suggested dropping the name Motur for the strata that overlie the Barakars, and proposed to refer to them as Barren Measures or Middle Damudas. The inlier visited by Dr. Fox is not, however, shown in Medlicott's map, and in any case it is clear from the text of his memoir[2] that the term Motur was selected to apply primarily to the rocks in the section to the west of Motur. Medlicott also applied the term to the rocks of the Pench Valley. There seems thus to be no valid reason for discarding this well-known term.

The Moturs in turn pass upwards quite conformably into the beds that were termed the Bijori horizon by Mr. Medlicott. It is consequently difficult to draw a dividing plane between the Bijoris and the Moturs. The Bijoris, however, contain carbonaceous shales and thin, poor coal seams, and in this manner show their relationships with the Raniganj series, which they represent. Mr. Crookshank has found numerous occurrences of *Glossopteris* in the Bijoris and has shown that the Almod (Alimod) beds can be assigned to the upper part of the Bijoris.

Dr. Fox crossed north-west from Suktawa (22° 24′ : 77° 51′) and Kesla (22° 28′ : 77° 51′) to the Nilgarh forest reserve and then southward along the scarp of the Pipalgota reserved forest to Jamgarh Hill (22° 16′ : 77° 46′) to study the great overlap of the Upper Gondwanas (chiefly Jabalpur beds) mapped by Mr. Crookshank in the previous season. There is no doubt that the Upper Gondwanas overlap the Lower Gondwanas southward and, according to Dr. Fox, the successive beds of the Upper Gondwanas overstep each other in the same direction. In Jamgarh Hill the Jabalpurs are found resting on the Moturs.

Dr. Fox was able to devote time also to the subject of the equivalence, suggested by him some years back,[3] of the Denwa series with the red clays and sandstones, known as the Moturs, in the Pench Valley. He found that the Moturs were quite conformable to the coal measures (Barakars) and thus equivalent to the Moturs of the type area as was recognised by Medlicott. The great lithological dissimilarity between the Moturs of the Pench Valley and those

[1] 'The Southern Coal-fields of the Satpura Gondwana Basin', *Mem. Geol. Surv. Ind.*, XXIV, pp. 46-48, (1887).

[2] *Op. cit.*, X, p. 161, (1873).

[3] *Rec. Geol. Surv. Ind.*, LIX, p. 86, (1926).

seen in the excellent sections of the Tawa River is due according to Dr. Fox to prolonged soaking and exposure of the strata in the Pench Valley. Not only has Dr. Fox found typical buff to greenish yellow clays in process of alteration to bright red clays, but he has also traced the influence of this prolonged soaking in causing an increase in the moisture contents and decrease of caking character of the Pench Valley coals in passing from west to east, though there are marked exceptions to these progressive changes.

Thus the result of Dr. Fox's work is to show that the doubt previously thrown by him on H. B. Medlicott's classification of the Gondwanas in the Satpura Range was unjustified[1] and that the Moturs of the type area and of the Pench Valley are the same, as was established by H. B. Medlicott; and that the Moturs are older than the Denwas (to some forms of which they are lithologically similar), as is required by Medlicott's classification. It is satisfactory to have the accuracy of H. B. Medlicott's classification of the Gondwanas in the Satpuras reinstated after the doubts cast on it in recent years. It is unfortunate that there should have been this period of doubt concerning the accuracy of H. B. Medlicott's classification as not only has it led to a large number of inaccurate statements on pages 85 and 86 of Vol. LIX of these *Records*, but also to an erroneous alteration of the position of the boundary between the Upper and Lower Gondwana rocks in the Satpuras on the latest (fifth) edition of the 32-mile to the inch geological map of India published in 1931. It has seemed desirable to draw attention to these errors, so as to prevent any further confusion. It is also important to notice that the work of the pioneers in Indian geology, of whom Mr. H. B. Medlicott was a distinguished member, deserves the greatest respect, and that significant changes in the classifications worked out by them should not be made without the very strongest reasons.

83. Mr. D. Bhattacharji spent three months in the field at the beginning of 1932, working partly in the Umrer tahsil in the Nagpur district on sheet 55P/1, and partly in the Gondia and Sakoli tahsils of the Bhandara district on sheet 55O/15.

**Nagpur district.**

The areas mapped in the Nagpur district are occupied mainly by the Deccan trap formation with a small amount of alluvium. The Deccan trap includes the hill of Mate Pahar Pipardol, 1,373 feet, where it is estimated the total

[1] *Rec. Geol. Surv. Ind.*, LIX, pp. 85, 86, (1926).

thickness of the lavas is somewhat less than 450 feet. This is also about the maximum thickness of the Deccan trap series in this area.

There are no fossiliferous intertrappean beds in this area; but unfossiliferous intertrappean bands about 3 to 5 feet thick have been noted by Mr. Bhattacharji near Tikari (20° 56′ : 79° 11′), Dawa (20° 54′ : 79° 10′), Thana (20° 55′ : 79° 6′), Chargaon (20° 51′ : 79° 5′), Makardhokra (20° 52′ : 79° 13′) and Sirpur (20° 51′ : 79° 15′). In most of these sandstones and clays are found. In other places a red clay marks the horizon between the successive flows.

**Bhandara district.**

84. In sheet 55 O/15 in the Bhandara district the major portion of the sheet is occupied by rocks allocated to the Sausar series and associated gneisses largely obscured by alluvium. But the south-east corner is occupied by rocks of the *Sakoli series* forming a continuation of the Gaikhuri Hills mapped by Dr. S. K. Chatterjee in sheet 55 O/16. The boundary between the Sausar and Sakoli tracts runs as usual in a north-easterly direction, from Bori (21° 15′ : 79° 53′) in the south-west to Dongargaon (21° 23′ : 80° 0′) in the north-east. The rocks of the Sakoli series as represented in this sheet comprise chloritic and ferruginous quartzites, phyllites and muscovite-chlorite-schists. The quartzites form two prominent bands, one from Setepar (21° 16′ : 79° 51′), on the southern margin of the map, through Wadegaon (21° 19′ : 79° 59′) to Dongargaon (21° 23′ : 80° 0′); and the other through the Bagimar and Ladhari hills, forming a continuation of the band previously mapped by Dr. Chatterji along the north-western fringe of the Gaikhuri Range of Government Reserved Forest in the sheet to the south. Chlorite-muscovite-schist is closely associated with these quartzites passing into them both vertically and marginally. Phyllites, regarded as higher in the sequence, occupy an extensive tract to the south-east of these schists.

The portion of the tract occupied by the *Sausar series* mapped this year is that immediately adjoining the Sakolis. The Sausar series is here represented by some minute exposures of amphibolite and by quartzites of the Ramtek stage near Lakhegaon (21° 21′ : 79° 55′). There is also a very small exposure of slightly manganiferous rock resembling gondite near Kesalwara (21° 20′ : 79° 52′), which is associated with felspathic gneissose schist. There are also numerous outcrops of gneisses and felspathic schists appearing through the alluvium, mainly in stream beds.

Three bands of *fault breccia* have been found, one near Berdipar Tola (21° 20′ : 79° 58′) with a north by west strike; the second half way between Bori and Lendejhari with an E. S. E. strike; and the third striking E. 30° N. along the south-eastern slope of Bagimar hill range. The last is a continuation of the fault breccia traced by Dr. S. K. Chatterjee in the sheet to the south. These fault breccias all occur in the tract occupied by the Sakoli series.

**Madras Presidency.**

85. Mr. A. L. Coulson spent the first three months of the year investigating the barytes and asbestos deposits of the Anantapur, Cuddapah, and Kurnool districts of the Madras Presidency. This work is summarised in the respective sections of 'Economic Enquiries'. Mr. P. N. Mukerjee assisted Mr. Coulson in this work.

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# ANTHRACOLITHIC FAUNAS OF THE SOUTHERN SHAN STATES. BY F. R. COWPER REED, M.A., Sc.D., F.G.S. (With Plates 1 and 2 and an APPENDIX BY STANLEY SMITH, M.A., D.Sc., F.G.S.)

## INTRODUCTION.

Of the three faunas of the Anthracolithic system of the Shan States described by Dr. Diener[1] in 1911 only one was obtained from the Southern Shan States, the fossils of which were collected from bands of shaly limestone and marl in the hills between Hopong and Mong Pawn. Dr. Coggin Brown has from time to time recently made considerable collections from a dark limestone at a locality in the Southern Shan States called Htam Sang (A. 534), and it is these which have provided the chief material for this memoir. But there are also a few specimens from other localities. One of them is a specimen of a coral from a black shattered limestone at Taung-gyi, belonging to the 'Plateau Limestones' which has been identified by Dr. Stanley Smith as *Lonsdaleia indica*, Waag., but no other fossil is available from this locality.

There is also a rather abundant coral belonging either to the genus *Syringopora* or to *Tetrapora* which occurs at Poila (A. 506).

The present author himself in 1927 visited some exposures on the road between Taung-gyi and Mong Pawn and collected a few specimens near the 24th milestone which are also here described, as they supplement the list given by Dr. Diener from the same neighbourhood, and some of them show features of special interest.

The description of the new species of *Lophophyllum* from Htam Sang has been kindly furnished by Dr. Stanley Smith, who has examined and cut several specimens of it for me, and it is here given as an appendix.

With the exception of this coral, of which a considerable number of specimens occur in the collection from Htam Sang, only one

[1] Diener, 'Anthracolithic Fossils of the Shan States', *Pal. Ind.*, N. S., Vol. III, Mem. No. 4, pp. 1-74, Pls. I-VII, (1911).

or two examples of the various species described below have been available, and in many cases the material has proved too imperfect for a full description or specific determination.

### Locality I: Htam Sang.

List of fossils collected by Dr. Coggin Brown.

*Liebea indica*, Waag.
*Derbyia grandis*, Waag.
„ *shanensis* (Diener).
*Streptorhynchus* cf. *pelargonatus*, Schloth.
„ cf. (*Kiangsiella*) *pectiniformis* (Dav.).
*Orthotetes* cf. *capuloides* (Waag.) ?
*Schuchertella semiplana* (Waag.).
*Strophalosia* sp.
*Productus* (*Krotovia*) cf. *janus*, Huang.
„ (*Marginifera*) cf. *kweichowensis*, Huang.
„ (*Dictyoclostus*) sp.
*Chonetes* sp.
*Camarophoria* cf. *nucula*, Schellw.
*Spiriferina* (*Spiriferellina*) *shanensis*, sp. nov.
„ (*Reticulariina*) *conquisita*, sp. nov.
*Squamularia asiatica*, Chao.
„ *duplex*, sp. nov.
„ ? *indica* (Waag.).
*Martinia dispar*, Diener ?
*Martiniopsis latouchei*, Diener ?
„ cf. *subpentagonalis*, Waag.
*Notothyris exilis*, Gemm. var.
„ *nucleolus* (Kut.).
„ *persimilis*, sp. nov.
*Athyris* (*Cleiothyridina*) *pectinifera*, Sow.
*Spirigerella prælonga*, Waag. var. nov. *shanensis*.
„ *derbyi*, Waag. var.
*Lyttonia nobilis*, Waag.
*Fenestella gemmata*, sp. nov.
„ *multinodulosa*, sp. nov.
„ sp. a.
„ sp. b.
*Polypora koninckiana*, Waag. and Pichl, var. nov. *postera*.
„ cf. *megastoma*, De Kon.

*Polypora* cf. *gigantea*, Waag. and Pichl.
,, cf. *kolvæ*, Stuck.
,, *discreta*, sp. nov.
,, ssp. ind.
*Thamniscus* cf. *dubius*, Schloth. ?
*Septopora* ? sp.
*Goniocladia indica*, Waag. and Pichl.
*Pinnatopora* sp.
*Acanthocladia* sp.
*Streblotrypa bassleri*, sp. nov.
,, *birmanica*, sp. nov.
*Rhabdomeson shanense*, sp. nov.
*Rhombopora circumcincta*, sp. nov.
,, *virgula*, sp. nov.
*Fistulipora servata*, sp. nov.
,, aff. *carbonaria*, Ulrich.
*Hexagonella lævigata*, Waag. and Wentz.
*Geinitzella* cf. *crassa*, Lonsd.
*Tabulipora* ? sp.
*Cyathocrinus virgalensis*, Waag.
*Michelinia dieneri*, sp. nov.
*Lophophyllum orientale*, St. Smith (sp. nov.).

LOCALITY II : TAUNG-GYI.

*Lonsdaleia indica*, Waag.

LOCALITY III : POILA.

*Syringopora ?* sp.

LOCALITY IV : NEAR 24TH MILESTONE ON ROAD FROM TAUNG-GYI TO MÖNG PAWN.

List of fossils collected by Dr. F. R. C. Reed in 1927.
*Derbyia* ? sp.
*Schuchertella semiplana*, Waag.
*Productus* (*Marginifera*) *bivius*, sp. nov.
*Aulosteges* cf. *tibeticus*, Diener.
*Chonetes* sp.
*Spiriferina* (*Spiriferellina*) *shanensis*, sp. nov.
*Squamularia asiatica*, Chao.
*Athyris* (*Cleiothyridina*) *pectinifera*, Sow.

*Fenestella jabiensis*, Waag. and Pichl.
„ sp.
*Polypora* cf. *kolvæ*, Stuck.
„ cf. *tranninhensis*, Mansuy.
„ ssp. ind.
*Rhabdomeson submurale*, sp. nov.
*Streblotrypa bassleri*, sp. nov.
*Cyathocrinus virgalensis*, Waag.
*Michelinia* cf. *yunnanensis*, Reed.
*Lophophyllum orientale*, St. Smith. sp. nov.

## LOCALITY I.—HTAM SANG.

### MOLLUSCA.

#### *Liebea indica*, Waagen.

There is one small left valve of this species in the collection from Htam Sang (A. 534), showing the characters which Waagen [1] has described. It measures 7 mm. in length. This is the only lamellibranch which has been recognised from Htam Sang.

### BRACHIOPODA.

#### *Derbyia grandis*, Waagen.

This species [2] which was not recorded by Diener from the Southern Shan States is only represented by one imperfect but typical valve from Htam Sang. When perfect this specimen must have measured about 45 mm. in length.

#### *Derbyia shanensis* (Diener).

There are some imperfect specimens in the present collection which may be referred to Diener's species *Streptorhynchus shanensis* [3] which he founded on specimens from Kehsi Mansam. With regard to the generic reference it seems much more probable that it should be placed in the genus *Derbyia*, particularly as Diener

[1] Waagen, Salt Range Fossils, I, *Pal. Ind.*, Ser. XIII, p. 295; Pl. XXIV, fig. 13, (1887).
[2] Waagen, Salt Range Fossils, I, *Pal. Ind.*, Ser. XIII, p. 597; Pl. LI, fig. 1, 1a-1c; Pl. LII, figs. 1, 3; Pl. LIII, figs. 3, 5, (1887).
[3] Diener, *op. cit.* p. 14; Pl. II, figs. 8a-c, 9, (1911).

himself specially compared it with *Derbyia biloba* (Hall)[1] It is difficult to understand Diener's statement that the hinge-line is 'little more than half the greatest breadth of the shell', as he also states on the same page that both valves are 'transversely elongated, being considerably broader than long'. Our best specimen which is transversely elliptical and thus resembles in shape the Mongolian shell which Grabau[2] names *Schellwienella regina*, has the pedicle-valve gently concave and forming a low, sharp pointed cone, with the large, triangular hinge-area nearly at right angles to the plane of the shell. The sharp, radiating riblets on the surface show slight scabrosity where they are crossed by the concentric lines. The least imperfect specimen measures about 43 mm. in length, 68 mm. in width and 34 mm. in depth at the apex of the pedicle-valve.

There is considerable difference of opinion as to the validity of the various generic names which have been given to the members of the Orthothetinæ, and Licharew[3] has recently discarded the names *Schellwienella*, *Schuchertella* and *Orthothetina* for Upper Palæozoic species. Grabau, however, as above mentioned, refers a Permian species to *Schellwienella*, and Dunbar and Condra[4] use *Schuchertella*, and *Orthothetina* for certain Pennsylvanian species and do not think Licharew's arguments are convincing. The genus *Derbyia* as re-defined by Dunbar and Condra[5] is apparently that to which Diener's species *shanensis* should be referred. Schuchert and Le Vene[6] have recently made the remark that *Derbyia* 'seems to be a synonym of *Orthotetes* Fischer 1829-1850'.

*Streptorhynchus* cf. *pelargonatus*, Schlotheim.

One nearly complete pedicle valve of an Orthothetoid shell and a less perfect one from the same locality are worthy of notice because of their well-preserved characters and distinctive ornamentation which differs from that in *D. shanensis* in the much smaller number of the radii. The pedicle-valve is gently convex, subtriangular

[1] Hall, *2nd Ann. Rept. New York State Geol.*, Pl. 41, figs. 4, 5, (1883).
[2] Grabau, Permian of Mongolia, *Nat. Hist. Centr. Asia*, IV, p. 248; Pl. XXV, figs. 2*a*, *b*, (1931).
[3] Licharew, Classification of Orthototinæ, *Ann. Soc. Pal. Russ.*, VIII, pp. 117-139, (1930).
[4] Dunbar and Condra, *Bull. Nebraska Geol. Surv.*, 5, Ser., pp. 66-75, (1932).
[5] *Ibid.*, pp. 75-78.
[6] Schuchert and Le Vene, *Foss. Catal.*, 1, Anim. Pars 42, Brachiopoda, p. 51, (1929).

in outline and forms a depressed cone with a high pointed umbo, the straight umbonal edges diverging from it at about 80°; the hinge-area is large and triangular and more than one third the height of the valve; the cardinal angles are subrectangular; the general outline of the shell, apart from the ·hinge-area, is transversely subelliptical. The surface of the valve is covered with 40—50 straight, narrow, rounded, prominent, equal or subequal, radiating riblets, nearly all equidistant and separated by rather deep, concave interspaces, about twice as wide as the riblets and crossed by strong, closely placed, concentric striæ; a few of the riblets become slightly thicker and more prominent towards the margins, and in a few interspaces a finer riblet is developed anteriorly. A concentric growth-ridge is also present in one specimen. There are also some other small and much worn specimens which may belong to the same species.

*Dimensions.*

| | |
|---|---|
| Length . . . . . . . . . . | 16·5 mm. |
| Width . . . . . . . . . . | 18·0 mm. |

*Remarks.*—This shell seems to be comparable, if not identical with *Streptorhynchus pelargonatus*, Schloth., which is the type of the genus, and was figured by Waagen [1] from the Salt Range. We may also compare *Str. broili*, Grabau,[2] from the Permian of Mongolia. It is perhaps identical with the shell from Namun figured by Diener [3] as *Str.* cf. *semiplanus*, Waag., or with the unfigured species from the same locality which he says bears a 'superficial resemblance to *Str. pelargonatus*' (*op. cit.*, p. 48). We may specially compare *Streptorhynchus memor*, Reed,[4] from the Salt Range, which was recognised to be closely allied to *Str. pelargonatus*, and the species *Str. affine*, Girty, from the Pennsylvanian of Kansas and Nebraska,[5] is undoubtedly closely related. Dunbar and Condra (*op. cit.*) remark that the latter species 'is probably closely allied to *Schuchertella pratteni* (McChesney)[6] and may mark the transition from *Schuchertella* to *Streptorhynchus*'. *Str. pyramidalis*, King,[7] from

[1] Waagen, Salt Range Fossils, I, p. 579, Pl. L, figs. 3-5, 7, (1887).
[2] Grabau, Permian of Mongolia, p. 245; Pl. XXIV, figs. 3, 4, (1931).
[3] Diener, *op. cit.*, p. 47; Pl. VII, figs. 8, 9, (1911).
[4] Reed, *Pal. Ind.*, Vol. XVII, p. 37, Pl. VI, figs. 3, 3*a*, (1931).
[5] Dunbar and Condra, *op. cit.* p. 122; Pl. XV, figs. 13-18*d*, (1932).
[6] *Ibid.*, p. 117; Pl. XV, figs. 1-10.
[7] King, Geology of the Glass Mountains, Pt. II, *Bull. Univ. Texas*, 3042, p. 50; Pl. IV, figs. 7-10, (1930).

the Glass Mountains of Texas, may be identical, and its founder notes its resemblance to *Str. pelargonatus* and to *Str. pseudo-pelargonatus*, Broili,[1] from Timor.

### *Streptorhynchus* (*Kiangsiella*) *pectiniformis* (Davidson) ?

The impression of part of the exterior of one valve of a small specimen is probably referable to this brachiopod,[2] for it shows the characteristic marginal radial plications. Its internal characters being unknown, we have to put a query to its reference, as some species of *Meekella* seem to be indistinguishable externally.[3] A species somewhat similar to *Str. pectiniformis* has been recently described from Western Australia under the name *Str. plicatilis*, Hosking.[4] There is a variety of *K. pectiniformis* described by Grabau and Chao[5] from the Chihsia limestone of China, but it seems more allied to *K. tingi*, Grabau, than to our fragmentary specimen.

### *Orthotetes* cf. *capuloides* (Waagen) ?

The internal cast of a small, complete shell with the umbonal region of the pedicle valve broken off, seems to be related to several of Waagen's species of *Streptorhynchus*, of which the internal characters have not been described. In our specimen the characteristic large flabelliform muscle-scar, subtruncate anteriorly and divided down the centre by a narrow, low ridge is visible and parts of the diverging dental plates can also be seen, and traces of the spondylium. In the brachial valve the muscle-scar seems to be large and cordate or subcircular in shape and it is also divided by a weak median ridge, but it is not well preserved. The ribbing shows on the interior of both valves and consists of fine, radial, thread-like lines, in places grouped in twos or threes. The brachial valve is deeper and more convex than the pedicle-valve, which is subconical, with a high beak, *Str. capuloides*, Waag.,[6] of the Middle Productus Limestone of the Salt Range may probably be considered as comparable.

[1] Broili, Perm. Brach. Timor, *Paläont. Timor*, Lief. VII, Abt. XII, p. 5; Pl. CXV (1), figs. 4, 5, (1916).

[2] Davidson, *Quart. Journ. Geol. Soc.*, XVIII, p. 30; Pl. I, fig. 17, (1862).

[3] Reed, *Pal. Ind.*, N. S., Vol. XVII, p. 38, (1931) (for references).

[4] Hosking, *Journ. R. Soc. Western Australia*, XVIII, p. 48; Pl. 5, figs. 5*a*, *b*, (1931-32).

[5] Chao, *Bull. Geol. Soc. China*, VI, No. 2, p. 106; Pl. 1, fig. 3, (1927).

[6] Waagen, *op. cit.*, p. 582; Pl. L, fig. 9*a*-*f*.

If we accept the key to the Orthotetinæ put forward recently by Dunbar and Condra [1] we must put our specimen in the genus *Orthotetes* rather than in *Streptorhynchus.*

*Schuchertella semiplana* (Waagen).

The Salt Range brachiopod described by Waagen[2] as *Orthotetes semiplanus* is represented in the collection from Htam Sang by one good brachial valve, measuring 16 mm. in length, and by fragments of others. The generic reference is still somewhat doubtful, but recently Dunbar and Condra, [3] following Girty,[4] have stated that Waagen erroneously used Fischer's generic name *Orthotetes* for the group of shells to which Girty has given the name *Schuchertella.* Chao [5] has compared a shell from the Chihsia limestone of Kiangsu with Waagen's species and likewise applied to it the generic name *Schuchertella.*

*Strophalosia* sp. (Pl. 2, fig. 15).

There is one flattened, or slightly concave, transversely sub-elliptical brachial valve of a productoid shell with a hinge-line rather less than its width, the cardinal angles being obtuse, and having its surface ornamented with fine, somewhat undulating, concentric lines and weak, irregular rugæ of unequal strength and with small, hollow pustules, which in the umbonal region are numerous, closely set, low and vertical, but towards the margins become larger, longer, oblique and more widely spaced, forming here recumbent tubular spines arranged in roughly concentric and quincunx order. We must apparently refer this specimen to some species of *Strophalosia*, but Waagen did not figure or describe such a brachial valve in any of his species from the Salt Range, though it is possible that our valve belongs to some form like *Str. nodosa*, Waag.,[6] or *Str. indica*, Waag.[7]

[1] Dunbar and Condra, *op. cit.*, pp. 66-75, (1932).
[2] Waagen, *op. cit.*, p. 608 ; Pl. LV, figs. 1, 2.
[3] Dunbar and Condra, *op. cit.*, p. 70, (1932).
[4] Girty, *Proc. U. S. Nat. Mus.*, 27, p. 734, (1904).
[5] Chao, *Bull. Geol. Soc. China*, VI, No. 2, p. 107 ; Pl. 1, fig. 4, (1927).
[6] Waagen, *op. cit.*, p. 652 ; Pl. LXIV, figs. 8, 9.
[7] *Ibid.*, p. 648 ; Pl. LXV, figs. 1-4. Broili, *op. cit.*, p. 27 ; Pl. 118 (4), figs. 9, 10, (1916).

*Dimensions.*

| | |
|---|---|
| Length . . . . . . . . . . | 13 mm. |
| Width . . . . . . . . . . | 17 mm. |

*Productus* (*Krotovia*) cf. *janus*. Huang.

The impression and cast of part of the surface of a broken brachial valve of a species of *Productus* in the collection from Htam Sang appears to be much like the shells, named and figured *Pr. abichi*, Waag., by Diener [1] from Kehsi Mansam, but it cannot be referred to that species. Our specimen has a subquadrate shape with the hinge-line rather less than the width of the valve and a large gently concave disk, weakly bilobed in its anterior half by a very low, rapidly widening, rounded fold; the margin of the valve (which is not well exposed) is gently geniculated, but the cardinal angles are horizontal and flattened and have slightly defined ears. The surface is closely covered with small, low, rounded pustules and shallow pits of subequal size, less than their own diameter apart posteriorly, but more widely spaced anteriorly, and arranged in broken, radial lines, while they become smaller towards the margins, but again larger and somewhat elongated near the edge; a rather coarse, concentric lineation is also present and there are a few, short, narrow, concentric rugæ near the cardinal line bending in and meeting it at an obtuse angle. The shell when perfect must have measured about 27 mm. in length and 30-35 mm. in width. We may, with great probability, consider that the species from the Upper Carboniferous of Chitral, which the present author [2] described as *Pr.* cf. *pseudoaculeatus*, Krotow, is identical with the present specimen, and its close resemblance to *Pr.* (*Krotovia*) *pustulatus*, Keys., was then specially noticed. Apart from the bilobation of the surface the ornamentation much resembles that of the shell from Laos, ascribed by Mansuy [3] to *Pr. nystianus*, De Kon. We may certainly refer our specimen to the subgenus *Krotovia* or *Avonia* rather than to the subgenus *Waagenoconcha*, to which *Pr. abichi* belongs. Several species of *Avonia* from Texas (*e.g.*, *A. meekana*, Girty [4]) have a very similar ornamentation. *Pr.* (*A.*) *echidniformis*,

[1] Diener, *op. cit.* p. 32, Pl. V, figs. 1-8, (1911).
[2] Reed, *Pal. Ind.*, N. S., Vol. VI, Mem. No. 4, p. 30; Pl. III, fig. 10, (1925).
[3] Mansuy, *Mém. Serv. Geol. Indochine*, 1, Fasc. 4, p. 16; Pl. IV, figs. 2a-h, (1912).
[4] King, *Bull. Univ. Texas*, 3042, p. 83; Pl. XX, figs. 4, 5, (1930).

Grabau, em. Chao, but[1] especially *Pr.* (*Krotovia*) *pustulatus*, Keys., which is figured by Chao[2] from China, seem allied to our specimen, which is unfortunately too imperfect for a satisfactory determination. Huang[3] has recently described a new species from S. W. China under the name *Krotovia* (*Avonia*) *janus* with which our specemen may be identical.

*Productus* (*Marginifera*) cf.*kweichowensis*, Huang. (Pl. 1, fig. 1).

A complete specimen of a species of *Marginifera* is imbedded in massive, black limestone so as to expose only the whole of the brachial valve and the umbo of the pedicle-valve. The shell is subovate, as long as wide; the hinge-line is rather less than the maximum width, the cardinal angles being obtuse or subrectangular. The pedicle-valve is much swollen and strongly convex; the umbo, which is broad, rounded, much inflated and elevated, rising above the hinge-line to a height of more than half the length of the brachial valve, is strongly incurved and has a sharp apex, slightly overhanging the hinge-line; the umbonal slopes are rounded and descend steeply to the small ill-defined ears; the surface seems to be smooth, except for some obscure traces of a few small tubercles on the umbo. The brachial valve is transversely elliptical in shape, rather deeply concave, and has small slightly flattened ears, indistinctly marked off; most of the surface is too much destroyed to distinguish any ornament, but in the anterior part of the middle region there are a few elongated small tubercles, and there is a well-preserved, strong, concentric, submarginal lamellose ridge, of which the edge is apparently armed with small fimbriations, which may represent the ends of short, marginal, radial liræ.

*Dimensions.*

| | |
|---|---|
| Length of shell . . . . . . . . . . | 19·0 mm. |
| Length of brachial valve . . . . . . , | 11·5 mm. |
| Width of brachial valve . . . . . . . | 18·0 mm. |

*Remarks.*—This shell agrees in some respects with examples of *Marginifera spinosocostata*, Abich,[4] and *M. helica*, Abich,[5] as figured

[1] Chao, *Palæont. Sinica*, Ser. B, V, Fasc. 2, p. 120; Pl. XIV, figs. 17-27, (1927).
[2] *Ibid.*, Fasc. 3, p. 52; Pl. V, figs. 18-20, (1928).
[3] Huang, *Palæont. Sinica*, Ser. B, IX, Fasc. 1, p. 55; Pl. IV, figs. 5, 6, (1932).
[4] Frech and Arthaber, *Beitr. Palæont. Oesterr. Ungarns*, XII, p. 262; Pl. XX, figs. 5-8, (1898).
[5] *Ibid.*, p. 265; Pl. XX, figs. 10-12; Diener, Himal. Foss., Vol. I, Pt. 5, p. 74; Pl. III, figs. 9*a*-*d*.

by Frech and Arthaber from Armenia, but it has a more inflated pedicle-valve and larger, broader beak and obtuse, instead of pointed, cardinal angles. Diener[1] has figured specimens from the Zewan beds of Kashmir, which he compares with the former species, but it is not known from the Productus Limestones of the Salt Range. Frech believed that Kayser's *Productus nystianus* var. *lopingensis* was the same as Abich's *M. helica*, but Chao[2] retains the name *lopingensis* for certain Chinese shells. It is much like some of Kayser's[3] specimens from China, termed *Prod. aculeatus*, Mart. var., which Chao includes in the same species. We may also doubtfully compare *Productus troianus*, Enderle,[4] from Asia Minor (particularly the specimen represented in Enderle's figure 12), a species which was thought to be allied to *Pr. aculeatus*, Mart. The Chinese species *M. jisuensis*, Chao,[5] which is considered comparable with *M. juresanensis*, Tschern.,[6] also seems to be allied to our shell, and the Russian species *M. involuta*, Tschern.,[7] to which *M. morrisi*, Chao,[8] is considered to be related, also appears to have many points in common with it. But *M.* (*Spinomarginifera*) *kweichowensis*, Huang,[9] from S. W. China seems most like it.

### *Productus* (*Dictyoclostus*) sp.

One imperfect brachial valve of a species of *Productus*, which occurs in the black limestone of Htam Sang, belongs to the *semireticulatus* group. Our specimen only shows part of the flattened disc of the valve which has a weak median depression ; the anterior part of the shell is seen to have been abruptly geniculated, but is hidden in the tough matrix. The ornamentation is well preserved and consists of regular, rather fine, equal, rounded radial liræ, occasionally bifurcating and crossed by equal regular rounded narrow concentric rugæ of the same width as the liræ, thus forming

[1] Diener, *Pal. Ind.*, N. S., Vol. V, Mem. No. 2, p. 82 ; Pl. VIII, figs. 13*a-d* ; Pl. IX, figs. 1, 2, (1915).

[2] Chao, *Palæont. Sinica*, Ser. B, 5, Fasc. 2, Product. I, p. 153 ; Pl. XVI, figs. 8-12, (1927).

[3] Kayser in Richthofen's ' China ', IV, Pl. XXVI, figs. 1, 2, (*non cet.*) (1884).

[4] Enderle, *Beitr. Palaeont. Oesterr. Ungarns*, XIII, p. 76 ; Pl. VII, figs. 7, 12, (1900).

[5] Chao, *op. cit.*, p. 149 ; Pl. XV, figs. 15-24, (1927). Grabau, Permian of Mongolia, p. 303 ; Pl. XXIX, figs. 15-24 ; Pl. XXX, figs. 15-19, (1931).

[6] Tschernyschew, *Mem. Com. Geol. Russ.*, XVI, Pt. 2, p. 652 ; Pl. LX, fig. 18, (1902).

[7] Tschernyschew, *op. cit.*, pp. 321, 645 ; Pl. XXXVI, figs. 7, 9, 13 ; Pl. LVIII, figs. 4-6 (1902).

[8] Chao, *op. cit.*, p. 152 ; Pl. XV, figs. 28-30, (1927).

[9] Huang, *op. cit.*, p. 56 ; Pl. V, figs. 1-11, (1932).

regular radial and concentric series of small rounded nodules. The cardinal angles seem to have been subrectangular or slightly obtuse, the concentric rugæ meeting the hinge-line nearly at right angles. Our specimen seems to be identical with those from Kehsi Mansam, which Diener [1] attributed to *Pr. gratiosus*, Waag., but this specific reference cannot be considered as correct.[2] Diener's *Pr. semireticulatus*, Mart., from Chitichun [3] seems to have very similar characters to our shell, and Mansuy's [4] *Pr.* cf. *transversalis*, Tschern., from Laos is perhaps identical with it. But there are so many species of the *semireticulatus* group which present closely similar characters in the brachial valve that we are unable to decide to what species it is most nearly allied.

### *Chonetes* sp.

There is one poor specimen of a species of *Chonetes* having a subquadrate shape and small, slightly pointed, depressed, cardinal angles. The pedicle-valve, which is alone known, is rather strongly convex and is bilobed by a broad, deep, rounded sinus, increasing in width anteriorly and widely notching the anterior edge. The surface is covered with numerous, fine, sharp, rounded, radial thread-like lines.

This specimen does not seem to be referable to any of those figured by Waagen from the Salt Range, but is probably allied to *Ch. mölleri*, Tschern. var. *carnica*, Gortani,[5] from the Carnic Alps or to *Ch. latesinuata*, Schellw., which Chao [6] figures from Shansi. A variety of this species has been described by the present author from Chitral.[7]

*Dimensio*

| | |
|---|---|
| Length | 5·0 mm. |
| Width | 8·0 mm. |

### *Camarophoria* cf. *nucula*, Schellwien.

There is one somewhat broken specimen of a much swollen, subcircular, rhynchonelloid measuring about 10 mm. in length and

[1] Diener, *op. cit.*, p. 27; Pl. IV, figs. 5-8, (1911).
[2] Diener, Himal. Foss, Vol. 1, Pt. 3, *Pal. Ind.*, p. 18; Pl. II, figs. 1, 3, 5; Pl. II, figs. 1, 2.
[3] Reed, *Pal. Ind.*, N. S., Vol. XVII, p. 3, (1931).
[4] Mansuy, *Mém, Serv. Geol. Indochine*, VII, Fasc. 1, p. 55; Pl. VI, fig. 8, (1920).
[5] Gortani, *Bull. Soc. Geol. Ital.*, XXIV, p. 538; Pl. XIV, figs. 16, 17, (1905).
[6] Chao, *op. cit.*, p. 22; Pl. II, figs. 3-12, (1928).
[7] Reed, *Pal. Ind.*, N. S., Vol. VI, Mem. No. 4, p. 81; Pl. III, fig. 5, (1925).

the same in width and about 7 mm. in thickness. The pedicle-valve is shallow, but strongly arched from back to front and shows a deep, wide, sharp-edged sinus, holding a pair of low, equal, narrow ribs on its flattened floor, each of which is divided near its end by a short median groove; the marginal ribs which form the edges of the sinus diverge strongly and rise steeply on each side, being very high, narrow and acutely angular at their front ends; there is one rather lower similar rib on each lateral lobe. The brachial valve is much inflated and has a low median fold, with raised angular edges anteriorly, but the middle of the fold (which is not well preserved) is depressed; the lateral lobes are smooth, except for the presence of one weak rib, and descend steeply on each side. The umbonal region is partly destroyed in both valves, and we do not know the internal characters. But we may compare this specimen with *Camarophoria nucula*, Schellw.,[1] from the Trogkofel beds rather than with *C. globulina*, Phill., from the Salt Range as figured and described by Waagen,[2] though the latter is a very variable species and many different forms of it have been recorded from the Permian of Europe and Asia. The figures of a shell from Timor attributed by Hamlet [3] to *C. nucula*, Schellw., do not much resemble our shell, but some of the small specimens which Broili [4] would include in *C. purdoni*, Dav., though utterly unlike the type of that species, bear a greater resemblance.

The author has recently described a variety of *C. nucula* under the name *saxatilis* [5] from the Productus Limestone of the Warcha section in the Salt Range, but it has several longer and stronger ribs on the valves, and three ribs occur in the sinus.

*Spiriferina (Spiriferellina) shanensis*, sp. nov. (Pl. 1, figs. 7-7*c*).

Shell transversely semielliptical, unequally biconvex; cardinal angles sharply rounded; hinge-line slightly less than maximum width of shell. Brachial valve convex, deeper than opposite valve, with narrow, prominent, subangular, steep-sided median fold, becoming higher and more angular in front: four slightly smaller, lower,

[1] Schellwien, *Abh. K. geol. Reichsanst.*, XVI, p. 100; Pl. XV, figs. 7, 8, (1900).

[2] Waagen, *op. cit.*, p. 443; Pl. XXXIII, figs. 13, 14.

[3] Hamlet, Perm. Brach., etc., Timor, *Jaarb. Mijn. Ned. Ind.*, Verh. II, (1928), p. 59; Pl. IX, figs. 1, 2, (1927).

[4] Broili, *Palæont. Timor, Lief.* VII, Abt. XII, p. 55; Pl. CXXV, (11), figs. 20-22 (*non cet.*) (1916).

[5] Reed, *Pal. Ind.*, N. S., Vol. XVII, p. 35; Pl. VI, figs. 1-1*c*, 2, (1931).

similar subangular folds occupy each lateral lobe, all of equal size but successively decreasing in height and the outer two curving slightly back; a fifth shorter and much smaller fold lies along the hinge-line; interspaces between lateral folds deep, acutely angular, equal, except the interspace on each side of the median fold which is larger and wider than the others. Pedicle-valve, with high, gently incurved, pointed beak, and concave, rounded umbonal edges diverging at 110°-120°; hinge-area high, triangular, concave, nearly vertical, with large, wide, triangular delthyrium; median sinus of valve deep, angular, simple; four subangular prominent folds on each lateral lobe, the inner ones being the largest and forming the elevated edges of the sinus, a fifth shorter, narrower, lower fold lying along the cardinal edge. Surface of both valves crossed by numerous regular, equidistant, rather thick, equal, imbricating concentric lamellæ. Shell-substance densely punctate.

*Dimensions.*

| | |
|---|---|
| Length of pedicle-valve . . . . . . | 8·5 mm. |
| „ brachial valve . . . . . . | 6·5 mm. |
| Width . . . . . . . . . . | 11·5 mm. |
| Depth . . . . . . . . . . | 5·5 mm. |

*Remarks.*—There is one complete example of this new species in the collection together with some fragmentary specimens. It differs from the Salt Range form of *Sp. cristata*, Schloth.,[1] in its curved lateral folds, smaller number of folds, narrower median fold and strong concentric lamellation, though one of Waagen's specimens of *Sp. cristata* has a similarly reduced number of folds. The species *Sp. ornata*, Waag.,[2] and *Sp. insculpta*, Phill.,[3] which are closely allied to each other (as Nikitin[4] has remarked) seem to be nearer our shell, and *Sp. subcristata*, Netsch.,[5] may also be mentioned. The name *Maia* was proposed in 1919 by Fredericks for the group comprising *Sp. ornata*, but it is pre-occupied, as Schuchert and Le Vene[6] have pointed out, and Pæckelmann[7] is

[1] Waagen, *op. cit.*, p. 499; Pl. XLIX, figs. 3-7.

[2] *Ibid.*, p. 505; Pl. L, figs. 1, 2.

[3] Davidson, Mon. Brit. Foss., Brach., II, p. 42; Pl. VII, figs. 48-55; *Ibid.*, IV, Pl. LII, figs. 14, 15. North, *Quart. Journ. Geol. Soc.*, LXXVI, p. 217; Pl. XIII, fig. 11, (1920).

[4] Nikitin, *Mem. Com. Geol. Russ.*, V, pp. 67, 166, (1888).

[5] Netschajew, *Mem. Com. Geol. Russ.*, N. S., Livr. 61, p. 90; Pl. XII, figs. 16, 17, (1911).

[6] Schuchert and Le Vene, *Amer. Journ. Sc.*, XVII, p. 120, (1929).

[7] Pæckelmann, *Neues Jahrb. f. Miner.*, etc., Beil. Bd. LXVII, Abt. B, p. 51, (193?).

probably correct in maintaining that it may be included in Fredericks' group *Spiriferellina.* We may observe that *Sp. insculpta* var. *indosinensis,* Mansuy,[1] from Cambodia bears a considerable resemblance to our species, and North's *Sp. octoplicata* mut. δ [2] is also comparable.

*Spiriferina (Reticulariina) conquisita,* sp. nov. (Pl. 1, figs. 8, 9.)

Shell transversely subtriangular, with more or less acutely pointed cardinal angles. Brachial valve gently convex, bearing three straight, strong, rounded radiating lateral folds on each side of the more elevated similar and scarcely wider median fold, all separated by deep, somewhat wider, concave interspaces; the outermost lateral fold lies along the hinge-line. Surface coarsely pustulate, being covered with numerous, prominent, equal and equidistant papillæ, each perforated by a minute apical pore.

*Dimensions.*

| | |
|---|---|
| Length . . . . . . . . . . | 8·5 mm. |
| Width . . . . . . . . . . | 11·5 mm. |

*Remarks.*—There is no resemblance of this species to *Sp. shanensis,* the rounded character of the folds, their small number and especially their papillate ornamentation being distinctive. Only one specimen in the collection, consisting of the left half of a brachial valve, has the surface well preserved. *Sp. spinosa,* Norw. and Pratt,[3] which belongs to Girty's [4] group *spinosa* and which Fredericks [5] chose as the genotype of his genus or subgenus *Reticulariina,* seems to be the nearest ally and *Sp. laxa,* Girty, [6] of the Guadalupian formation, etc. may also be compared.

Grabau's species *Sp. mongolica* [7] bears a considerable resemblance to our species in shape and widely separated folds.

*Squamularia asiatica,* Chao.

The Permian shells which Waagen,[8] Mansuy, Broili and others referred to *Reticularia lineata* (Martin) of the Lower Carboniferous

[1] Mansuy, *op. cit.*, III, Fasc. 3, p. 23 ; Pl. III, figs. 3*a-k*, (1914).
[2] North, *op. cit.*, p. 217 ; Pl. XIII, fig. 9, (1920).
[3] Norwood and Pratten, *Journ. Acad. Nat. Sci. Philadelphia,* Ser. 2, p. 71 ; Pl. 9, fig. 1, (1856).
[4] Girty, *U. S. Geol. Surv.* Prof. Paper 108, p. 373, (1908).
[5] Fredericks, *Mem. Com. Geol. Russ.*, N. S., Livr. 156, p. 16, (1916).
[6] King, *Bull. Univ. Texas,* 3042, p. 122 ; Pl. XLII, figs. 7-11, (1930).
[7] Grabau, *op. cit.*, p. 206 ; Pl. IX, pp. 5, 6, (1931).
[8] Waagen, *op. cit.*, p. 540 ; Pl. XLII, figs. 6-8.

of England have been long recognised as distinct, and Chao [1] has recently placed them in a new species of *Squamularia* and carefully defined it under the name *Sq. asiatica.* There is one good example of a pedicle-valve of this species from Htam Sang, showing the ornamentation and measuring 20 mm. in length and 25 mm. in width. The validity of the genus *Squamularia* has been frequently disputed, but Dunbar and Condra [2] are amongst the most recent supporters of its separation from *Reticularia.*

*Squamularia duplex,* sp. nov. (Pl. 1, figs. 4-4*d*).

Shell transversely subcircular, rather wider than long, unequally biconvex. Pedicle-valve convex, with rather high, swollen beak, slightly incurved, rising well above that of opposite valve; umbonal slopes rounded; hinge-area small, concave, triangular, steeply inclined. Brachial valve transversely elliptical, wider, shorter and less convex than other valve, with small, slightly elevated and incurved beak. Surface of valves ornamented with numerous rather thick, imbricating, concentric lamellæ of equal or subequal width, bearing on their surface a series of closely placed, equidistant, small, fine, recumbent, hollow spine-bases, each of which expands and swells towards its anterior end; immediately in front of them, and alternating with them on the edge of each lamella, there is an equal number of similar but smaller and much shorter spine-bases, sub-tubercular in character.

*Dimensions.*

| | |
|---|---|
| Length of pedicle-valve . . . . . . . | 14·0 mm. |
| Width of pedicle-valve . . . . . . . | 14·0 mm. |
| Thickness of shell . . . . . . . . | 10·0 mm. |
| Length of brachial valve . . . . . . . | 12·5 mm. |

*Remarks.*—In general characters this species much resembles *Squamularia ovata,* Chao,[3] from China, but the double series of marginal spines on each lamella is a distinct feature. *Sq. asiatica,* Chao,[4] is also closely allied but in both of these species the inner and outer marginal series of recumbent spines on the lamellæ are much more numerous and finer.

[1] Chao, *Palaeont. Sinica,* Ser. B, XI, Fasc. 1, p. 91; Pl. XI, figs. 12-14, (1929).
[2] Dunbar and Condra, *op. cit.,* p. 311, (1932).
[3] Chao, *Palaeont. Sinica,* Ser. B., XI, Fasc. 1, p. 89, Pl. VIII, figs. 20-22, (1929).
[4] Chao, *Palaeont. Sinica,* Ser. B., XI, Fasc 1, p. 91; Pl. XI, figs. 12-14, (1929).

*Squamularia ? indica* (Waagen).

The Salt Range species which Waagen[1] described as *Reticularia indica*, but which Chao[2] refers to *Squamularia*, is represented by one large pedicle-valve measuring 60 mm. in length. The presence of minute spines on the edges of the thin concentric lamellæ is only visible in a few places of our specimen, and we may doubt if the shell is truly referable to *Squamularia*. Grabau[3] has recorded this species from the Permian of Mongolia.

*Martinia dispar*, Diener ?

There is one large crushed specimen of a species of *Martinia* showing the pedicle-valve and measuring about 80 mm. in transverse width which probably belongs to the species *M. dispar*, Diener,[4] which has only been described from the Southern Shan States. But it is too imperfect for a precise determination.

*Martiniopsis latouchei*, Diener ?

This species which Diener[5] founded on specimens from Kehsi Mansam seems to be represented only by one poor example from Htam Sang which is weathered out partially on the surface of a slab of rock and measures 28 mm. in length and 40 mm. in width.

*Martiniopsis* cf. *subpentagonalis*, Waagen.

The posterior part of a crushed pedicle-valve of a shell with a transversely elliptical shape, measuring 40-50 mm. in width, appears to be comparable with one example of the species *Martiniopsis subpentagonalis*, Waagen[6] from the Lower Productus Limestone of the Salt Range, for it shows the pair of long, very slightly divergent dental plates in the interior, and in its external shape, long hinge-line and other characters it bears a close resemblance. Leidhold[7] and Pæckelmann[8] do not see any reason to separate the genus *Martiniopsis* from *Martinia*, but this opinion is not generally

[1] Waagen, *op. cit.*, p. 842 ; Pl. XLIII, fig. 6 ; Pl. XLIV, fig. 21.
[2] Chao, *op. cit.*, p. 96, (1929).
[3] Grabau, *op. cit.*, p. 200 ; Pl. XVIII, figs. 2-4, (1931).
[4] Diener, *op. cit.*, p. 4 ; Pl. I, fig. 1, (1911).
[5] Diener, *op. cit.*, p. 7 ; Pl. 1, figs. 3-5 ; Pl. III, fig. 2, (1911).
[6] Waagen, Salt Range Fossils, 1., p. 527 ; Pl. XLIII, fig. 1.
[7] Leidhold, *Abh. Preuss. geol. Landesanst.*, N. F. 109, pp. 76-85, (1928).
[8] Pæckelmann, *op. cit.*, p. 47, (1932).

held, and George[1] states that the genotype of *Martinia* (*Spirifer glaber*, Mart.) has no dental plates whereas Leidhold declares that it possesses them, as does *Martiniopsis*.

### *Notothyris exilis*, Gemmellaro, var.

There is one small example of a species of *Notothyris* from Htam Sang showing the brachial valve and beak of the pedicle-valve, which may be attributed to a variety of *N. exilis*, Gemm. It much resembles the example from Chitichun figured by Diener[2], but it is rather broader and thus approaches *N. subveiscularis* (Dav.)[3] in shape, though Waagen[4] figured a specimen from the Salt Range with 7-8 short folds round the margin whereas our specimen has only four on the anterior portion of the valve and these not more than one fifth its length. *N. irregularis*, Grabau,[5] from the Permian of Mongolia, may be compared, and *N. schuchertensis*, Girty,[6] of the Guadelupian fauna is allied.

*Dimensions.*

| | |
|---|---|
| Length . . . . . . . . . . | 10·5 mm. |
| Width . . . . . . . . . . | 8·5 mm. |

### *Notothyris nucleolus* (Kutorga).

This well-known species[7] is represented by one or more imperfect specimens from Htam Sang. Diener[8] has figured it from Namun in the Northern Shan States.

### *Notothyris persimilis*, sp. nov. (Pl. 1, figs. 5-5*d*).

Shell biconvex, somewhat compressed anteriorly, sub-ovate, elongated, subtruncate anteriorly, widest in front of middle. Pedicle-valve longer and more convex than opposite valve, having much elevated, prominent, narrow, sub-tubular umbo, rising high

[1] George, *Geol. Mag.*, LXIV, p. 110, (1927).
[2] Diener, Himal. Foss., 1, Pt. 5, *Pal. Ind.* Ser. XV, p. 39; Pl. II, figs. 16*a-d*, (1903).
[3] Davidson, *Quart. Journ. Geol. Soc.*, XVIII, p. 27; Pl. I, fig. 4, (1862).
[4] Waagen, *op. cit.*, p. 378; Pl. XXVIII, figs. 3*a-d*, 4.
[5] Grabau, *op. cit.*, p. 115; Pl. VII, fig. 6, (1931).
[6] Girty, *U. S. Geol. Surv.* Prof. Paper 58, p. 336; Pl. XV, figs. 25-25*c*, (1908).
[7] Broili, *op. cit.*, p. 66; Pl. CXXVI, (12), fig. 4; Pl. 127 (13), figs. 8-10, 12-15 (and references), (1916).
[8] Diener, *op. cit.*, p. 53; Pl. VII, figs. 13, 14, (1911).

above that of brachial valve, gently incurved and truncated by large, circular, apical foramen; umbonal shoulders rounded, long and diverging with a gently concave curvature at about 30°; inner umbonal slopes below apex somewhat excavated; surface of pedicle-valve convex, strongly arched from back to front, somewhat flattened transversely towards anterior end, having, a shallow, rounded, narrow, median sinus for more than half its length, widening anteriorly and bounded by a pair of narrow, low, sharply rounded, slightly divergent folds which increase slightly in height in front, having on each side of them a short, shallow, rounded similar sinus, thus producing three small, but well-marked, narrow undulations on the anterior margin; the lateral margins of the valves unite in a simple wide curve. Brachial valve moderately convex, most so posteriorly, with three weak low sharply rounded folds near its anterior margin corresponding to the sinuations in the opposite valve, the median one being the strongest; umbo high, sharply pointed, swollen, rising well above hinge-line gently incurved and having concave lateral shoulders, thus causing a gentle undulation in the posterior lateral union of the valves. Surface of shell ornamented with a few, regular, thin, concentric, lamellose growth-ridges and striæ and covered with very fine punctæ arranged closely in minute undulating, concentric lines.

*Dimensions.*

| | |
|---|---|
| Length of pedicle-valve . . . . . . . | 12·0 mm. |
| ,, brachial valve . . . . . . . | 10·0 mm. |
| Width . . . . . . . . . . | 9·0 mm. |
| Depth of shell . . . . . . . . | 6·5 mm. |

*Remarks.*—There are two good specimens of this species, the larger of which has the measurements above given. It is closely allied to *Notothyris ovalis*, Gemm., as figured by Schellwien [1] from the Trogkofel beds, and less closely to *N. nucleolus* (Kut.)[2] and to *N. mediterranea*, Gemm.,[3] though the two latter species vary somewhat in shape. Our new species has a more elongated and prominent beak to the pedicle-valve and longer and more sloping shoulders

[1] Schellwien, Fauna, Trogkofelsch., *Abh. k. geol. Reichsanst.* XVI, p. 103; Pl. XV, figs. 9-12, (1900).

[2] Broili, Palæont. v. Timor, Lief. VII, Abt. XII, p. 66; Pl. CXXVI (12), fig. 4; Pl. CXXVII (13), figs. 8-10, 12-15, and references (1916), Grabau, Permian of Mongolia, p. 111; Pl. V, figs. 3a-d; Pl. VIII, figs. 7, 8, (1931).

[3] Gemmellaro, Fauna, calc. Fusul., Fasc. 4, Pt. 1, p. 244; Pl. XXVI, figs. 1-6; Pl. XXVII, fig. 59; Gortani, *Palæont. Ital.*, XII, p. 47; Pl. III, figs. 17, 18, (1906),

than either of them; and the beak of the brachial valve is more like that of *Spirigerella minuta*, Waag. As above remarked, Diener recorded *N. nucleolus* from the Shan States, but it is not the same species as the one here described. But the form from Chitichun figured by Diener[1] as *N. mediterranea*, Gemm., is very much like our species, and it is probable that the shell from the Permian of Timor compared by Broili[2] with *N. mediterranea*, Gemm., is identical with it.

### *Athyris* (*Cleiothyridina*) *pectinifera* (Sowerby).

This typically Permian species, as interpreted by Tschernyschew and Netschajew [3] from the Upper Carboniferous of the Urals and Permian of Russia and by Ozaki [4] from China, is represented by several small specimens from Htam Sang, varying in shape from circular to subelliptical. One of our specimens measuring 12 mm. in width and 11 mm. in length has the surface of the brachial valve weathered away exposing the interior and the spiralia; there is a thin median septum reaching less than half the length of the valve, and the spiralia, which point forwards and outwards and nearly touch the anterior lateral edges of the shell, consist of 9-10 coils. This species has also been found by the author on the Taung-gyi-Möng Pawn road. It is probable that many of the shells recorded from the Permian of various localities in Asia as *A. roissyi*, L'Ev., should be placed in *A. pectinifera*, for they show no fold or sinus on the valves, are uniformly biconvex and have coarser and fewer concentric fringed laminæ on the surface.

### *Spirigerella derbyi*, Waagen, var.

This variable species is represented by one complete, but partially imbedded, specimen which resembles the more oval form with higher beaks to both valves which Waagen [5] illustrates from the 'middle Productus Limestone on the road between Vurcha [=Warcha]

[1] Diener, Himal. Foss., I, Pt. 5, *Pal. Ind.*, Ser. XV, p. 38; Pl. II, figs. 14, 15. (? Pl. III, fig. 14), (1903).

[2] Broili, *op. cit.*, p. 68; Pl. CXXVII (13), figs. 11, 16-21, (1916). Hamlet, *op. cit.*, p. 71, (1927).

[3] Tschernyschew, *op. cit.*, pp. 102, 511; Pl. XLIII, figs. 4-6, (1902); Netschajew, *Mem. Com. Geol. Russ.*, N. S., Livr. 61, p. 96; Pl. XIII, figs. 8-15, (1911).

[4] Ozaki, Up. carb. Brach. N. China, *Bull. Shanghai Sc. Instit.*, I, No. 6, p. 177; Pl. XV, figs. 20, 21, (1931).

[5] Waagen, *op. cit.*, p. 453; Pl. XXXVI, fig. 12.

and Uchali', but it is unlike the commoner, more pentagonal and subcircular forms with wider umbonal angle as figured by him.[1]

*Spirigerella praelonga*, Waagen, var. nov. *shanensis* (Pl. 1, figs. 6-6*d*).

Shell elongated oval, narrow, carinated, pointed in front, swollen, with long sloping shoulders extending to middle of shell. Pedicle-valve strongly arched from back to front, somewhat flattened behind transversely, produced in front into acutely pointed angular tongue; surface with narrow subangular median sinus arising in front of umbo, and increasing in depth anteriorly, angulating anterior half of valve; umbo high, sharp, incurved. Brachial valve deep, with median subangular carination, the sides steeply sloping down and more or less flattened; umbo high, prominent, sharply pointed. Union of valves forming a broad sigmoidal undulation on each side of umbo and curving up sharply in front to form acutely angular median junction. Surface marked with concentric growth-lines, strongest near the margin. Shell substance densely punctate.

*Dimensions.*

| | |
|---|---|
| Length . . . . . . . . . . | 15·0 mm. |
| Width . . . . . . . . . . | 11·0 mm. |
| Thickness . . . . . . . . . | 9·0 mm. |

*Remarks.*—The shell is more sharply carinated and is more acutely pointed in front than the typical Salt Range species *Sp. praelonga*, Waagen,[2] and has also a deeper median sinus, and it somewhat resembles *Sp. minuta*, Waag.[3] It is much like the variety of *praelonga* from the Salt Range which the present author has called *carinata*,[4] but it has a more pointed anterior end and more deeply grooved pedicle-valve. *Composita persinuata* (Meek)[5] from the Glass Mountains of Texas bears a considerable external resemblance.

*Lyttonia nobilis*, Waagen.

This well-known species[6] is represented by one interior of a large shell measuring over 50 mm. in length. It has not previously

[1] *Ibid.*, Pl. XXXV, figs. 4-7, 9-13.
[2] Waagen, *op. cit.*, p. 457; Pl. XXXVII, figs. 10*a-d*.
[3] Waagen, *op. cit.*, p. 460; Pl. XXXVIII, figs. 3-4.
[4] Reed, *Pal. Ind.*, N. S., Vol. XVII, p. 30; Pl. V, figs. 9, 9*a-d*, (1931).
[5] King, *Bull. Univ. Texas*, 3042, p. 130; Pl. XLIII, figs. 18, 19, (1930).
[6] Waagen, *op. cit.*, p. 398; Pl. XXIX, figs. 1-3; Pl. XXX, figs. 1, 2, 5, 6, 8. Reed, *Pal. Ind.*, N. S., Vol. XVII, p. 39, (1931).

been recorded from the Southern Shan States. Hamlet [1] who records it from Timor considers it and the other Salt Range species *L. tenuis*, Waag., to be identical with *L. richthofeni*, Kayser, but Grabau [2] and Huang [3] retain Waagen's name, and Mansuy [4] has likewise done so for the Indo-Chinese examples. Girty's species *L. americana* [5] from the Guadalupian of Texas seems to be closely allied, and recently King [6] has put it as merely a variety of the Salt Range *L. nobilis*. The species *L. nobilis* appears to have been recognised only in beds of Permian age, and is specially characteristic of that formation throughout Asia.

## BRYOZOA.

### *Fenestella gemmata*, sp. nov. (Pl. 2, fig. 2).

Zoarium composed of regular, parallel, closely placed, thick, straight branches, less than their width apart, connected at equidistant intervals by very short, stout, depressed, horizontal dissepiments, rather irregularly alternating, narrower than the branches, but swollen in the middle into a low, rounded boss, as high as the branches. Branches with narrow median keel separating the two rows of regular, large, equidistant pores set at about their own diameter apart, not projecting laterally, and numbering 3 4 to each fenestrule with usually one at the base of each dissepiment. Fenestrules elongated, narrow, subelliptical, of equal size, about twice as long as wide, rather narrower than the branches. 10-11 branches occur in a transverse width of 5 mm. and 5-6 fenestrules in a length of 5 mm.

*Remarks.*—The striking peculiarity of this species is the swollen nature of the dissepiments on the poriferous face of the zoarium. Ulrich's species *Hemitrypa uspera*, [7] from the Keokuk formation, has the swellings on the reverse face of the dissepiments and therein differs from our species, but the closely placed branches and short-

[1] Hamlet, Perm. Brach. etc. Timor, Jaarb. *Mijn. Ned. Ind.* Verhand. II, p. 31; Pl. VI, figs. 1-4, (1927).

[2] Grabau, *op. cit.*, p. 285; Pl. 28, figs. 3-6, (1931).

[3] Huang, *op. cit.*, p. 89; Pl. VII, figs. 9, 10; Pl. VIII, figs. 8, 9; Pl. IX, figs. 1-8, (1932).

[4] Mansuy, *op. cit.*, II, Fasc. 4, p. 123, Pl. XIII, fig. 10, (1913). *Ibid.*, III, Fasc. 3, p. 32; Pl. VI, figs. 7*a-d*; Pl. VII, figs. 1*a-c*, (1914).

[5] Girty, *U. S. Geol. Surv.* Prof. Paper 58, p. 212; Pl. IV, figs. 8-8*b*; Pl. XXV, figs. 1-3*a*, (1908).

[6] King, *Bull. Univ. Texas*, 3042, p., 103; Pl. XXXI, figs. 10-13; Pl. XXXII, figs. 1-9, (1930).

[7] Ulrich, *Geol. Surv. Illinois*, VIII; p. 563, Pl. LVII, figs. 4, 4*a-f*, (1890).

ness of the dissepiments and comparatively few and large pores on the branches recall more than one species of this genus. However, in our specimen there is no trace of the presence of any tegmen as in *Hemitrypa*, so that we must refer it to the genus *Fenestella*. The zoarium of *F. saraneana*, Stuck.,[1] seems to resemble our species in the character of the branches and pores, but it has no swollen dissepiments, and apart from this feature we may especially compare *F. pulchradorsalis*, Bassl,,[2] from the Permian of Timor.

*Fenestella multinodulosa*, sp. nov. (Pl. 2, figs. 1, 1*a*).

Zoarium composed of rather thick but small parallel branches rarely bifurcating, connected by depressed, stout dissepiments at regular intervals, forming equal subquadrate to subcircular fenestrules. Branches with carina bearing numerous, prominent, equidistant, rounded nodules, about 3 to each fenestrule; zoœcia large, projecting into fenestrules, few in number, one only in the middle of each fenestrule and one invading the base of each dissepiment, which is expanded for it at its junction with the branches. 9-10 fenestrules to every 5 mm. longitudinally, and 9-10 branches to every 5 mm. transversely.

*Remarks.*—This small zoarium of which some of the specimens are beautifully preserved is marked by the coarse nodules along the carina. The small number and arrangement of the pores and shape of the fenestrules is much like *F. parviuscula*, Bassler,[3] of the Permian of Timor and *F. elusa*, Reed,[4] from the Permian of Yunnan. Perhaps Diener's[5] *F. perelegans*, Meek, from Namun is referable to our new species. *F. pectinis*, Moore,[6] of the Pennsylvanian of Texas, appears to be almost identical with it, and the West Australian species *F. horologia*, Bretnall,[7] is also comparable.

*Fenestella* sp. *a*.

The reverse face of a zoarium of a species of *Fenestella* with small meshes shows 9-10 fenestrules in a longitudinal distance of

[1] Stuckenberg, *Mem. Com. Geol. Russ.*, X, No. 3, pp. 149, 234; Pl. XXI, fig. 16, (1895).
[2] Bassler, Perm. Bryoz. Timor, *Palæont. Timor*, Lief. XVI, Heft 28, p. 74; Pl. CCXLIV (16), fig. 12, (1929).
[3] Bassler, *op. cit.*, p. 76; Pl. 241 (17), figs. 8-13, (1929).
[4] Reed, *Pal. Ind.*, N. S., Vol. X, Mem. No. 1, p. 114; Pl. XI, figs. 12-14, (1927).
[5] Diener, *op. cit.*, p. 56; Pl. VII, figs. 18, 19, (1911).
[6] Moore, *Journ. Palæont.*, III, No. 1, p. 18; Pl. 2, figs. 8-10, (1929).
[7] Hosking, *Journ. R. Soc. Western Australia*, XVII, p. 13; Pl. IV, fig. 3, (1930-31).

5 mm. and 11-13 in the same transverse distance. The branches are straight, parallel and occasionally bifurcate, and they bear a few irregularly distributed small prominent nodes and granules; the dissepiments are rather thinner than the branches, and equidistant. The fenestrules which are subquadrate to subelliptical in shape, and about 1½ times as long as wide, are wider than the branches and alternate with considerable regularity. We hesitate to refer this form to *F. perelegans*, Meek, though the size of the fenestrules and their number in a given distance are closely similar.

### *Fenestella ?* sp. *b.*

The reverse face of part of a zoarium of a species of a bryozoan, probably referable to *Fenestella* rather than to *Polypora*, shows a series of narrow, straight, rounded, regular, parallel, or slightly divergent branches, rarely bifurcating and connected by extremely slender, straight, horizontal, depressed dissepiments, set up at equal distances apart and forming subquadrate fenestrules about 4-5 times as wide as the branches. The branches are not all of the same thickness, but are all finely granulated, and there are also irregularly distributed on them, a few small, sharp nodes or pustules. In a longitudinal distance of 5 mm. there are 5-6 fenestrules and in a similar transverse distance there are 6-7. The feature of some of the branches being thicker than others is peculiar, but it is found in *F. surculosa*, Eichw.,[1] from the Upper Carboniferous of Russia, which resembles our specimen also in the thinness of the dissepiments, but not in the regularity of their disposition.

### *Polypora koninckiana*, Waagen and Pichl. var. nov. *postera*. (Pl. 2, figs. 11, 11*a*).

Zoarium composed of rather thick, rounded, somewhat flattened, subparallel, slightly flexuous branches occasionally bifurcating, mostly less than their width apart and connected at irregular intervals by very short, narrower depressed dissepiments, the branches usually approaching each other at the junctions. Poriferous surface rounded, occasionally unevenly swollen or transversely constricted; pores small, circular, widely separated, about twice their

[1] Stuckenberg, *op. cit.*, p. 143; Pl. XXI, figs. 3, 4, (1895).

diameter apart, arranged alternately in 4-6 rather irregular longitudinal rows, and having a general diagonal distribution; some of the pores, especially those along the edges of the fenestrules, are elevated on small projecting tubercles, and there are a few specially large prominent pores on larger swellings or mammillæ irregularly scattered about on the branches; the dissepiments usually bear 1-2 pores at each end of their base and occasionally one or more in the middle. Fenestrules elongated, oval, of rather unequal length.

*Dimensions.*

| | |
|---|---|
| Length of portion of zoarium . . . . . | c. 28 mm. |
| Width of portion of zoarium showing ten parallel branches . . . . . . . . | 18 mm. |
| Average width of branches . . . . . | 1·5-1·75 mm. |
| Length of fenestrules . . . . . | 3·0-3·5 mm. |

*Remarks.*—According to Bassler,[1] the genus '*Thamniscus* differs from *Polypora* in that the branches bifurcate more freely and the dissepiments are either entirely wanting or occur at very irregular and much longer intervals'. The two genera are thus undoubtedly very closely allied, and the reference of this species is rather uncertain; but the fairly regular disposition and frequency of the dissepiments inclines us to place it in the somewhat multiform genus *Polypora*, and their great reduction in length and occasional poriferous character as well as the general features of the zoarium indicate that it is closely allied to the first figured specimen of *P. koninckiana*, Waag. and Pichl, from the Salt Range. From the typical *P. koninckiana*, however, it differs in the irregular subnodulose surface of the branches and especially in the elevation and prominence of some of the zoœcia, thus resembling *P. timorensis*, Bassler,[3] from the Permian of Timor and *P. valida*, Moore, [4] from the Pennsylvanian of Texas, but it is to the Salt Range species as here restricted that it shows the closest relations, and it may be regarded as a variety of it. The larger zoœcia raised on the mammillæ are probably of the nature of gonocysts.

[1] Bassler, *op. cit.*, p. 80, (1929).
[2] Waagen and Pichl, Salt Range Fossils, I, p. 783; Pl. LXXXVII, figs. *a-d*. (*non* Pl. LXXXVIII, fig. 4; Pl. XC, fig. 1).
[3] Bassler, *op. cit.*, p. 79; Pl. 243, figs. 1-4.
[4] Moore, *Journ. Palæont.*, III, 2, p. 123; Pl. 15, fig. 11; Pl. 16, fig. 18, (1929).

*Polypora* cf. *megastoma*, De Koninck ?

The bryozoan which Waagen and Pichl[1] identified as *Polypora megastoma*, De Koninck, is represented by several poor fragments of zoaria (A. 534) in the collection from Htam Sang, but there is reason to doubt the identity of the European Lower Carboniferous form with that from the Productus Limestones of the Salt Range.

*Polypora* cf. *gigantea*, Waagen and Pichl.

Portions of several zoaria of a species of *Polypora* occur in the collection showing the poriferous and non-poriferous faces. They are not well preserved, but appear to be comparable to *P. gigantea*, Waag. and Pichl,[2] from the Salt Range. Loczy[3] figured a zoarium from Pupiao, Yunnan, which he likewise compared with this species and Mansuy[4] has also figured a specimen from the Fusulina Limestone of Laos.

*Polypora* cf. *kolvae*, Stuckenberg.

The reverse side of a portion of one zoarium shows characters which suggest that it is comparable with *P. kolvae*, Stuck.,[5] to which species Diener[6] considered a specimen from Namun and the author specimens from Chitral[7] to be allied. The branches are regularly parallel, and are connected at fairly regular intervals by horizontal thinner dissepiments, not expanded at their ends, forming oblong fenestrules of which there are about three in 10 mm. longitudinally and five in 10 mm. transversely. The branches are rounded and very finely granulated on the surface.

*Polypora discreta*, sp. nov. (Pl. 2, figs. 5-5*b*).

There is one good specimen of this species which is somewhat like that above recorded as *Polypora* cf. *gigantea*, but it differs in the great rarity of dissepiments, in the slenderer branches, in the

[1] Waagen and Pichl, *op. cit.*, p. 785; Pl. LXXXVIII, figs. 3, 5-7; Pl. LXXXIX, fig. 3(?).
[2] Waagen and Pichl, *op. cit.*, p. 786; Pl. LXXXIX, figs. 1, 2*a-c*.
[3] Loczy, Beschr. Palæont. Stratigr. Result. Reise Graf Szechenyi in Ost Asien, p. 131; Pl. VI, fig. 19, (1898).
[4] Mansuy, *Mem. Surv. Geol. Indo-China*, Vol. 1, Fasc. 4, p. 11; Pl. 1, fig. 6, (1912).
[5] Stuckenberg, *op. cit.*, pp. 163, 238; Pl. XXIII, fig. 4, (1895).
[6] Diener, *op. cit.*, p. 60; Pl. VII, fig. 25, (1911).
[7] Reed, *Pal. Ind.*, N. S., Vol. VI, Mem. No. 4, p. 20; Pl. II, figs. 8-9*a*, (1925).

smaller number, greater prominence and less regular diagonal arrangement of the zooecia and in the presence of interstitial granules between them.

The branches themselves are subparallel, slightly flexuous, cylindrical, and slender, and they occasionally bifurcate at acute angles; on their poriferous face there are 3-4 rows of small zooecia forming prominent papillæ arranged in diagonal lines, with a few minute granules, irregularly scattered between them and becoming more numerous on the sides of the branches. The branches are 2-3 times their diameter apart. The dissepiments, which are few and at rather irregular intervals apart, are thin, rounded, depressed and without zooecia. The reverse face of the zoarium is unknown. The whole portion of the zoarium, of which a portion is here figured, is about 40 mm. across, and in this space there are about 20 branches. The branches themselves measure 1·0-1·5 mm. in diameter. Although there are 17-20 branches of our specimen exposed there are only 2-3 dissepiments visible between a few of them on one side of the zoarium, but this may be due to the fact that the branches are partly embedded in the matrix and that the dissepiments are much depressed. We may probably regard *P. hirsuta*, Moore,[1] from the Pennsylvanian of Texas, as allied, but it has much thicker dissepiments and the branches are closer together. *P. testacelia*, Moore[2] may also be compared.

*Thamniscus dubius*, Schlotheim ?

There are some small fragments of zoaria in a poor state of preservation, which are with considerable hesitation referred to the Salt Range bryozoan which Waagen and Pichl[3] identified with *Thamniscus dubius*, Schlotheim. Bassler[4] figures an example from the Permian of Timor, and doubts its identity with the European form.

*Goniocladia indica*, Waagen and Pichl.

The reverse face of portions of several zoaria show rather large, irregularly polygonal meshes of somewhat unequal size without any clearly differentiated branches and dissepiments. The meshwork has the face subangular or sharply rounded, and the surface

[1] Moore, *op. cit.*, p. 25; Pl. III, figs. 17-19, (1929).
[2] *Ibid.*, p. 24; Pl. 3, figs. 9, 10.
[3] Waagen and Pichl, *op. cit.*, p. 808; Pl. XCIII, figs. 4*a*-*b*.
[4] Bassler, *op. cit.*, p. 80; Pl. 145 (21), fig. 12, (1929).

is smooth or very minutely granular. The poriferous face is unknown amongst our specimens. This bryozoan is referable to *G. indica*, Waag. and Pichl,[1] of the Productus Limestone of the Salt Range and is related to *Goniocladia* [ *Polypora* ] *concatenata*, Eichwald.[2] of the Upper Carboniferous of the Urals and to *G. timorensis*, Bassl.,[3] of the Permian of Timor, while *G. americana*, Girty,[4] of the Guadelupian of Texas, is also allied.

## *Pinnatopora* sp.

The reverse face of two small branches of a pinnate zoarium shows a very slender, rod-like, nearly straight stipe giving off on one side an equally slender straight branch (of which a long piece is preserved) diverging at an angle of about 45°. Both bear very short smaller lateral branches of equal length alternating on opposite sides at regular intervals and making an angle of about 50° with the stem. On the long branch which measures about 14 mm. in length there are 15 of these short lateral branches on each side. No internal structure is visible. We may probably compare *Pinnatopora striata*, Ulr.,[5] from the Keokuk group of Ohio, and *P. oculata*, Moore,[6] from the Pennsylvanian of Texas.

## *Acanthocladia* sp.

A portion of the reverse face of a species of *Acanthocladia* is exposed on the same slab of rock as that bearing the numerous stems of *Rhabdomeson shanense*, sp. nov., described below. It consists of a slender straight stipe about 6 mm. long, marked with delicate longitudinal striations and giving off rather more slender parallel lateral branches alternately at regular intervals on each side. These branches, of which only the bases of eight are preserved on one side, are rounded and diverge at about 75° from the stipe; on the other side of the stipe one of the branches has nearly 3 mm. of its length preserved and curves slightly forwards. The species from Timor described by Bassler as *A. rectifurcata*, sp. nov.,[7] seems to be almost identical.

[1] Waagen and Pichl, Salt Range Fossils, I. *Pal. Ind.*, Ser. XIII, Vol. 1, p. 805; Pl. XCIII, fig. 3, (1885).

[2] Stuckenberg, *op. cit.*, p. 168; Pl. XXIV, fig. 1, (1895).

[3] Bassler, *op. cit.*, p. 89; Pl. 247, figs. 8-13, (1929).

[4] Girty, *U. S. Geol. Surv.* Prof. Paper 58, p. 154; Pl. VIII, figs. 3-3c, (1908).

[5] Ulrich, *op. cit.*, pp. 362, 617; Pl. LXVI, fig. 4d, (1890).

[6] Moore, *op. cit.*, p. 125; Pl. 15, figs. 4, 5, 10, (1929).

[7] Bassler, *op. cit.*, p. 84; Pl. CCXLIV (20), figs. 7-12.

*Streblotrypa birmanica*, sp. nov. (Pl. 2, fig. 14).

There are some somewhat worn, small, cylindrical branches of a rod-like bryozoan and one much better preserved one, about 7 mm. long, here figured which must be referred to the genus *Streblotrypa*, and they somewhat resemble *Streblotrypa major*, Ulr.,[1] from the Keokuk group of Illinois. In our specimens there are 10-12 longitudinal rows of zoœcia in the circumference separated by somewhat sinuous longitudinal raised lines; the zoœcia alternate in adjoining rows, thus forming diagonal series and are their own length apart; each zoœcium is oval and has a raised peristome which is continued as a hood down from the aperture to form the longitudinal but weaker line on each side to the next zoœcium below, these lines enclosing a somewhat depressed small area of subrhomboidal shape nearly as long as the zoœcium and holding generally four minute pits or mesopores in two rows. At the base of each group of pits there is sometimes a minute nodule or pustule (? acanthopore). We may compare Bassler's species from Timor which he has named *Str. germana*,[2] but the longitudinal lines are rather less continuous in his figured specimens and the zoœcia are smaller, but there seems to be considerable variation in these characters. *Str. marmionensis*, Ether. jun.,[3] from Western Australia is also closely allied to our new species.

*Streblotrypa bassleri*, sp. nov. (Pl. 2, fig. 8).

The diagnosis of this species is based on the specimen from the exposure on the road from Taung-gyi to Mong. Pawn which is somewhat better preserved than that subsequently obtained from Htam Sang, and it is therefore given in the description of the fauna from Locality IV (*q.v.*). This specimen from Htam Sang differs from the type (fig. 7) in having rather more longitudinal series of zoœcia and in the zoœcia being rather less widely separated, but we can hardly regard it as distinct.

***Rhombopora circumcincta***, sp. nov. (Pl. 2, figs. 9, 9*a*, 10).

Zoarium consisting of cylindrical, straight, solid stems, bifurcating rarely into two similar equal branches diverging at about 75°.

[1] Ulrich, *op. cit.*, p. 666; Pl. LXXI, figs. 8, 8*a-d*, (1890).
[2] Bassler, *op. cit.*, p. 67; Pl. 239 (15), figs. 6-10.
[3] Hosking, *Journ. R. Soc. Western Australia*, XVII, p. 14; Pl. IV, fig. 1; text fig. 1, (1930-31).

Zoœcia small, oval, widely separated, with narrow raised peristomes, arranged alternately in 12-15 regular parallel and diagonal series on its circumference, but without longitudinal ridges between them; zoœcia about $1\frac{1}{2}$ times their length apart longitudinally and once to twice their width apart transversely; inter-apertural walls thick and bearing a rather irregular ring of minute, hollow, acanthopores in one or two somewhat irregular rows surrounding each zoœcium, with occasionally a larger acanthopore at its base.

*Dimensions.*

| | |
|---|---|
| Diameter of stem . . . . . . | c. 2·5 mm. |
| 11-13 zoœcia in . . . . . . | 5·0 mm. longitudinally. |

*Remarks.*—This species is referable to the genus *Rhombopora* because of its solid stems, while in the possession of a ring of acanthopores round each zoœcium it resembles *Rh. incrassata*, Ulrich,[1] of the Keokuk formation, and more especially *Rh. corticata*, Moore,[2] of the Pennsylvanian of Texas. *Rh. multigranulata*, Bretnall,[3] from West Australia is also comparable.

*Rhombopora virgula*, sp. nov. (Pl. 2, fig. 12).

Zoarium composed of a solid cylindrical, straight stem, occasionally giving off a branch at right angles, bearing on its circumference 20-22 regular straight parallel longitudinal and less obviously diagonal rows of small oval or elliptical zoœcia rather closely placed and alternating in adjacent rows, the walls of the zoœcia less than half their diameter in thickness and bearing a single ring of minute round hollow pustules (acanthopores) with an occasional larger one at the base or at the side of a zoœcium; the longitudinal ridges between the zoœcia are regular, continuous, parallel, straight and rarely flexuous.

*Dimensions.*

| | |
|---|---|
| Diameter of stem . . . . . . | 3·5 mm. |
| 12-14 zoœcia in . . . . . . | 5·0 mm. longitudinally. |

*Remarks.*—The walls are much thinner than in *Rhombopora circumcincta*; the linear longitudinal arrangement of the zoœcia

[1] Ulrich, *op. cit.*, p. 652; Pl. LXX, figs. 12, 12*a*.
[2] Moore, *op. cit.*, p. 137; Pl. 17, figs. 3, 4, (1929).
[3] Bretnall, *Bull. Geol. Surv. West Australia*, 88, p. 25; Pl. 1, fig. 3, (1926).

is much more strongly marked and the zoœcia are rather more numerous. The stem is certainly solid, so that we must refer the species to the genus *Rhombopora.* None of the species from Timor seem to be much like it.

### *Rhabdomeson shanense*, sp. nov. (Pl. 2, fig. 3).

Zoarium composed of small, cylindrical, straight, slender, hollow stems, rarely bifurcating, bearing 10–18 regular diagonal rows of small zoœcia sunk in rhomboidal vestibular areas; zoœcial apertures oval; walls somewhat thickened and exsert, with a single large prominent acanthopore at the base of each rhomboidal area forming a spinous tubercle. Axial tube large. The diagonal rows intersect at an angle of about 30°–45°.

*Dimensions.*

| | |
|---|---|
| Diameter of stem . . . . . . | 2·5–3·0 mm. |
| 12–14 zoœcia in . . . . . . | 5·0 mm. (diagonally). |

*Remarks.*—This species which is very abundant on some slabs of rock and is represented by many well preserved fragments of stems up to 48 mm. in length is much like the so-called *Rh. rhombiferum* (Phill.)[1] which Loczy [2] figured from the Upper Carboniferous of China. According to Bassler [3] *Rhabdomeson* differs only from *Rhombopora* in having a slender axial tube, and in imperfect or imbedded specimens this is difficult or impossible to see, but many of our specimens show it well. Our species cannot be referred to the true *Rh. rhombiferum* (Phill.) of the Lower Carboniferous of the British Isles, though it is allied to it as well as to *Rh. gracile* (Phill.), and it differs from *Rh. decorum*, Moore, [4] in the apparent absence of a ring of small acanthopores surrounding the zoœcia. *Rh. lepidodendroides*, Meek,[5] which bears a very great resemblance to our species is usually referred to the genus *Rhombopora.*

[1] Phillips, Geol. Yorkshire, Pt. II, p. 192; Pt. I, figs. 34, 35, (1836).
[2] Loczy, Beschr. Pal. Stratigr. Result. Graf. Szechenyi Exped. in Ostasien, p. 97, Pl. III, fig. 22, (1898).
[3] Bassler, *op. cit.*, p. 69, (1929).
[4] Moore, *op. cit.*, p. 147; Pl. 17, fig. 20.
[5] Meek, Palæont. Eastern Nebraska, p. 141; Pl. VII, figs. 2*a*-*f*, (1872). Nickles and Bassler, *Bull. U. S. Geol. Surv.*, 173, p. 395, (1900). Girty, Bull. *U. S. Geol. Surv.*, 544, p. 46 (for references), (1915).

*Fistulipora servata*, sp. nov. (Pl. 2, figs. 4, 4*a*).

Zoarium consisting of stout, subcylindrical, sublobate, hollow branches occasionally bifurcating, with the surface somewhat irregularly swollen or undulating. Zocecia numerous, subcircular, thick-walled, prominent, elevated above general surface, mostly closely set and often nearly in contact, directed somewhat obliquely to the surface (particularly around maculæ) and arranged in nearly regular diagonal and longitudinal lines; peristome swollen; lunarium distinct, semi-circular. Maculæ rare, small, irregular in shape, depressed, with the bordering zoœcia further apart than the rest. Interstitial tissue little developed, dense, composed of very small thin walled mesopores.

*Remarks*.—Two fragmentary branches occur in the collection, of which one stem measures 7-8 mm. in diameter and has 11-12 zoœcia in 5 mm. of a diagonal row. The most marked features of the species are the prominence and regular linear arrangement of the zoœcia and their oblique direction to the surface. The swollen elevated oblique peristomes of the zoœcia recall *Fistulipora labiata*, Keys.,[1] of the Upper Carboniferous of Russia, but in that species they have not such a regular close arrangement. We may also compare *F. carbonaria*, Ulr., especially the immature specimen of the variety *nebraskensis*, figured by Girty [2] from the Wewoka formation of Nebraska.

*Fistulipora* aff. *carbonaria*, Ulrich.

A small portion of a thin incrusting species of *Fistulipora* shows a series of closely set small, recumbent zoœcia, arranged in somewhat irregular, curved or straight, horizontal and diagonal rows. The zoœcia open very obliquely to the surface and form small, rounded, subtrigonal or semilunate elevations, with the semicircular or lunate apertures all facing the same way with great regularity; a lunarium on the outer lip is present; the peristomes are not swollen; and the zoœcia in the same row are often nearly or quite in contact laterally. There are 8-10 zoœcia in a horizontal distance of 5 mm. The maculæ are small and indistinctly defined, but the neighbouring zoœcia seem to be smaller, more closely and radially arranged round

[1] Stuckenberg, *Mem. Com. Geol. Russ.*, V, No. 4, p. 7; Pl. IV, figs. 31-37, (1888).
[2] Girty, *Bull. U. S. Geol. Surv.*, 544, p. 45; Pl. XXVI, fig. 6, (1915).

them. The interstitial tissue seems to be solid, but no section of the zoarium has been made. We may regard this species as allied to *Fistulipora carbonaria*, Ulrich,[1] which Girty[2] figures from the Wewoka formation of Oklahoma, the inclination of zoœcia to the surface and their close and regular arrangement and semilunate apertures being closely similar.

### *Hexagonella lævigata*, Waagen and Wentzel.

Diener[3] has described and figured *H. ramosa*, Waag. and Wentz.,[4] from Namun, but in the present collection there are three fragments of a flattened, lobate, bifurcated zoarium which more closely resembles *H. lævigata*, Waag. and Wentz.[5] There is another allied species *H. turgida*, Bassler,[6] occurring in the Permian of Timor. The outlining ridges of parts of the hexagonal areas can be distinguished in our specimens, and the other superficial characters of the species are clearly seen.

### *Geinitzella* cf. *crassa* (Lonsdale).

On the same slab of rock as that bearing the numerous fragments of *Rhabdomeson shanense*, sp. nov., there is one fragment of a small, hollow, cylindrical zoarium, measuring about 6·5 mm. in diameter, which bifurcates at its upper end at an angle of about 75° into two rather smaller branches. The surface shows small equal or subequal, subcircular, or oval, thin-walled zoœcia irregularly arranged, and there are minute polygonal acanthopores occasionally wedged in singly at each angle between them, or more rarely 2-4 lie at the sides; in some places a ring of small mesopores ? surrounds a zoœcium or an irregular group is intercalated. Other specimens occur in the collection from Htam Sang. This bryozoan may be ascribed to the genus *Geinitzella* and ressembles *G. crassa*, Lonsd., as figured by Waagen and Wentzel[7] from the Salt Range. Grabau[8] records a variety of the wide-spread species *G. columnaris* from the

[1] Ulrich, *Journ. Cincinnati Soc. Nat. Hist.*, 7, p. 45; Pl. III, figs. 1, 1*a*, (1884).
[2] Girty, *Bull. U. S. Geol. Surv.*, 544, p. 44; Pl. XXVI, fig. 5, (1915).
[3] Diener, *op. cit.*, p. 55; Pl. VII, fig. 16, (1911).
[4] Waagen and Wentzel, Salt Range Fossils, I, p. 912; Pl. CVI, figs. 3, 4; Pl. CVII.
[5] *Ibid.*, p. 915; Pl. CVIII, fig. 2*a-d*; Pl. CXV, fig. 5.
[6] Bassler, *op. cit.*, p. 51; Pl. CCXXXII (8), figs. 3-9, (1929).
[7] Waagen and Wentzel, *op. cit.*, p. 884; Pl. CXIV, figs. 1-3.
[8] Grabau, Permian of Mongolia, p. 46; Pl. I, figs. 10-12, (1931).

Permian of Mongolia, which Waagen and Wentzel[1] had long previously figured from the Salt Range, but this species is less like our specimen and the name has been somewhat loosely used.

### *Tabulipora* sp.

The genus *Tabulipora*, Young, which Bassler now[2] considers to be separable from *Stenopora*, Lonsdale, seems to be represented by some small, hollow, cylindrical, ramose zoaria, of which the best preserved specimen measures 7 mm. in diameter and 15 mm. in length. The zoœcial apertures are polygonal, mostly hexagonal and of equal or subequal size, except in the rare slightly depressed maculæ where a few of them are rather larger. The cell walls are thin. Minute spiniform acanthopores occur at the junction angles in some cases. There are about 16–20 zoœcia in a length of 5 mm. We may perhaps compare this form with *Stenopora rudis*, Ulr.,[3] but the maculæ in that species are elevated. *T. acadica*, Bell,[4] from the Windsor formation of Nova Scotia, also seems to be allied, but *T. cava*, Moore,[5] from the Pennsylvanian of Texas, may perhaps be considered as most like it.

## ACTINOZOA.

### *Lophophyllum orientale*, Stanley Smith (sp. nov.).

(*see* Appendix, p. 128).

### *Michelinia dieneri*, sp. nov. (Pl. 2, figs. 6, 6*a*).

Corallum small, irregularly lobate or ramose, forming flattened or irregularly subcylindrical stout branches. Corallites few, exsert, polygonal to subcircular, of rather unequal size, the smaller ones being irregularly distributed. Calices deep, circular; walls rather thick, with exsert lips showing a series of small fimbriations or nodules round their edges and radial striæ in the cup. Average diameter of calices 0·5–1 mm. Average diameter of branches 3-8 mm.

[1] Waagen and Wentzel, *op. cit.*, p. 822; Pl. CVI, figs. 5, 6; Pl. CXII, figs. 1-5; Pl. CXIII, figs. 1-4; Pl. CXV, fig. 1.

[2] Bassler, *op. cit.*, pp. 58, 60, (1929).

[3] Ulrich, *op. cit.*, p. 444; Pl. LXXII, figs. 8-8*b*.

[4] Bell, *Mem. Geol. Surv. Canada*, 155, p. 105; Pl. X, figs. 1-5, (1929).

[5] Moore, *op. cit.*, p. 7; Pl. I, figs. 13-15, 20, (1929).

*Remarks.*—This is the coral which Diener[1] figured from Möng Pawn as *Michelinia* (?) sp. and said that it resembled in its growth *M. abichi*, Waag. and Wentz., but we may better compare *M. parasitica* (Phill.)[2] which Stuckenberg[3] has recorded from the Upper Carboniferous of Russia. Weller[4] has remarked that his *Favosites valmeyerensis* from the Fern Glen formation, Missouri, is a close ally of Phillips' species. *M. minima*, Stuck.,[5] is another allied species, and *M. eugeneæ*, White,[6] may also be compared. *Pachypora jabiensis*, Waag. and Wentzel,[7] from the Salt Range, which has a somewhat similar mode of growth and appearance does not possess the marginal fimbriations round the lips of the calices which are also not exsert. None of the species of *Michelinia* to which Heritsch[8] refers bear much resemblance to our new form, nor do any of those from the Permian of China described by Yoh and Huang.[9]

## CRINOIDEA.

### *Cyathocrinus virgalensis*, Waagen.

Isolated stem-joints of this species[10] are common in the collection from Htam Sang, and fragments of the plates of the calyx occasionally occur.

## LOCALITY II.—TAUNG—GYI.

### *Lonsdaleia* (*Waagenophyllum*) *indica*, Waagen and Wentzel.

A small piece of black shattered limestone from behind Taunggyi has been kindly examined for me by Dr. Stanley Smith in order to determine the obscure coral which is preserved in it, and he states that a thin section indicates the Salt Range species *Lonsdaleia indica*, Waag. and Wentz., which was also described by Diener[11]

[1] Diener, *op. cit.*, p. 66; Pl. VI, fig. 11, (1911).
[2] Phillips, Geol. Yorks, Pt. II, p. 201; Pl. I, fig. 623, (1836).
[3] Stuckenberg, *op. cit.*, p. 118; Pl. XVIII, fig. 3, (1895).
[4] Weller, *Bull. Geol. Soc. Amer.*, 20, p. 274; Pl. 10, figs. 1, 2, (1909).
[5] Stuckenberg, *Mém. Com. Géol. Russ.*, X, No. 3, p. 326; Pl. XIV, figs. 7*a-c*, (1895).
[6] Girty, *Bull. U. S. Geol. Surv.*, 544, p. 29; Pl. II, figs. 11, 11*a*, (1915).
[7] Waagen and Wentzel, *op. cit.*, p. 847; Pl. XCVII, figs. 2*a*, 2*b*.
[8] Heritsch, *Sitz. Akad. Wiss. Wien*, Math. Nat. Kl. Abt. 1, Bd. 137, Heft 10, pp. 759-766, (1928).
[9] Yoh and Huang, *Palaeont. Sinica*, Ser. B, VIII, Fasc. 1, pp. 21-24, (1932); Huang, *Ibid.*, Fasc. 2, pp. 92-103, (1932).
[10] Waagen, *op. cit.*, p. 825; Pl. XCVI, figs. 13-15.
[11] Diener, *op. cit.*, p. 43; Pl. VI, fig. 4.

from Kehsi Mansam. Recently A. Sen[1] has been led to the conclusion that *L. indica* is identical with *L. virgalensis*, Waag. and Wentz., and it should be remembered that Dr. Stanley Smith had previously[2] suggested that *L. virgalensis* might be only a smaller variant of the larger species *L. indica* which has been described from the Upper Carboniferous of Chitral[3] as well as from the Productus Limestones of the Salt Range and Indo-China. A form comparable with *L. virgalensis* occurs also in the Upper Carboniferous of Tibet.[4] Huang[5] has recently described a variety of *L. indica* from the Permian of Kweichow, and Ozawa[6] regards Mansuy's *L. indica* from Indo-China as identical with *L. timorica*, Gerth, from Timor and Japan.

## LOCALITY III.—POILA.

*Syringopora* ? sp.

There is an abundant fasciculate coral from this locality (A. 506) constituting the only recognisable fossil, but unfortunately it is mostly in a poor state of preservation and the internal structure is nearly always completely obliterated by crystalline calcite, so that it is difficult to decide whether to refer it to the genus *Syringopora*, Goldfuss, or to the less known genus *Tetrapora*, Yabe and Hayasaka.

The corallites consist of cylindrical subparallel slightly flexuous, tubes with a diameter from 1·5–1·75 mm. and they are subcircular or circular in transverse section, but not quadrate or rhombic as in typical members of *Tetrapora*. The corallites are mostly their own diameter apart, but may be in contact in places and are sometimes arranged in a loose irregular chain-like fashion. The connecting tubules, which are rare and hardly ever seen, occur quite irregularly, but occasionally are shown in cross sections. Where the cateniform arrangement is developed there are wide spaces between the chains of corallites, 2–4 times their diameter. The walls of the coralites are thick and simple, and in some cases show

[1] Sen, *Quart. Journ. Geol. Min. Metall. Soc. India*, III, No. 1, pp. 9-11; Pl. I, (1931).
[2] Reed, *Pal. Ind.*, N. S., Vol. VI, Mem. No. 4, p. 15, (1925).
[3] *Ibid.*, p. 14; Pl. I, figs. 24-27.
[4] *Ibid.*, XVI, p. 14, (1930).
[5] Huang, *Palaeont. Sinica*, Ser. B, VIII, Fasc. 2, p. 48; Pl. III, figs. 1, 2; text fig. 3, (1932).
[6] Ozawa, *Journ. Coll. Sc. Imper. Univ. Tokyo*, XLV, p. 74; Pl. XIII, figs. 7, 8, (1925).

low internal longitudinal septal? ridges, but these are mostly obscure, though apparently not accidental or secondary thickenings of the walls. There are no tabulæ visible. The type of the genus *Tetrapora* is T. *elegantula*. Yabe and Hayasaka,[1] which has many connecting tubules; and in it the corallites are rhombic or subquadrate in section and close together and have a peripheral vesicular zone and horizontal tabulæ. But Huang says that the peripheral vesicles may not be developed, and he considers that the distinctive character of *Tetrapora* by which it differs from *Syringopora* is that the tabulæ are complete and horizontal, though he qualifies this statement by saying that—

> 'infundibuliform tabulæ are not entirely absent in *Tetrapora*....thus rendering the corallites indistinguishable from those of *Syringopora*. Such a character, however, is confined to 3 or 4 tabulæ, those above and below them remain more or less horizontal or slightly inclined'

As regards the shape of the corallites it is the case that in more than one species of *Tetrapora* (*e.g. T. nakingensis*, Yoh, *T. syringoporoides*. Yoh, and *T. laxa*, Yoh) the corallites are more often rounded or subcircular than polygonal. Such is certainly the case in our specimens from Poila, for irregularly shaped corallites in cross-sections seem to be rather accidental, though where the tubules are given off the circumference is slightly distorted, and judging from the figures of the various Chinese species of *Tetrapora* this often accounts for their non-circular shape. The absence of septal spines or ridges which is adjudged to be one of the features of *Tetrapora* is doubtful in our specimens, but they are often invisible in undoubted members of *Syringopora*. The present author has described two corals from the Upper Carboniferous of Tibet under the names *Syringopora gemina*[2] and *S. catenoides*[3] which seem to be most like the specimens from Poila, as is indicated from an examination of sections both in a longitudinal and transverse direction. But by a comparison with the figures and descriptions of the figures given by Yoh and Huang (*op. cit.*) of certain Chinese species of *Tetrapora* we cannot fail to observe a great resemblance to *T. syringoporoides*, Yoh,[4] and to *T. laxa*, Yoh,[5] which Huang[6]

[1] Yoh and Huang, *Palæont. Sinica*, Ser. B., VIII, Fasc. 1, p. 13; Pls. 1-3, (1932). Huang, *ibid.*, Fasc. 2, p. 105; Pl. XIV, figs. 1-4, (1932).

[2] Reed, *Pal. Ind.*, N. S., Vol. XVI; p. 6; Pl. IV, figs. 1, 1*a*, (1930).

[3] *Ibid.*, p. 12; Pl. III, figs. 5, 5*a*.

[4] Yoh, *op. cit.*, p. 20; Pl. III, figs. 3*a*, *b*.

[5] *Ibid.*, p. 19; Pl. IV, figs. 1*a*-*c*.

[6] Huang, *op. cit.*, p. 108.

considers almost indistinguishable, while the occasional cateniform arrangement of the corallites suggests the species *T. halysitoides* Yoh.[1] The genus *Tetrapora* is characteristic of the Chihsia limestone in China.[2]

## LOCALITY IV. NEAR 24TH MILESTONE ON ROAD FROM TAUNGGYI TO MONG PAWN.

### *Derbyia ?* sp.

The greater part of the brachial valve of a large orthotetoid shell, with, the cardinal area of the opposite valve attached, occurs in the collection from this locality. The valve is gently convex and has a weak median depression and somewhat flattened cardinal angles, and its shape, when perfect, was apparently transversely subcircular with rounded cardinal angles. The umbonal and middle regions of this valve are somewhat broken and crushed, but the cardinal area of the opposite valve is preserved and is seen to be large and triangular and is inclined nearly at right angles to the plane of the shell; there is also preserved the large convex triangular plate covering the delthyrium. The surface of the brachial valve is ornamented by numerous narrow, rounded scabrous, equidistant, sharply elevated, radial riblets of equal size, set at 2-3 times their thickness apart and there is very rarely a shorter, finer one intercalated; the lateral riblets curve back slightly, but the rest are straight, and all are crossed by narrow concentric lamellæ forming upon them small, regular, equidistant, closely imbricating convex scabrosities; but there are only fine concentric lamellose striæ crossing the concave interspaces. There are about 12-14 radii in a space of 10 mm. Our specimen, when perfect, must have measured about 60 mm. in width. As Diener[3] says that a strong concentric sculpture is absent in *D. shanensis* it results that our shell must belong to another species, and it seems in its ribbing more to resemble the unnamed species of *Streptorhynchus ?* which Diener[4] figures and describes from Kehsi Mansam.

[1] Yoh, *op. cit.*, p. 17; Pl. III, figs. 1*a-c*, 2*a*, *b*.
[2] Chao, *Bull. Geol. Soc. China*, VI, No. 2, p. 85, (1927).
[3] Diener, *op. cit.*, p. 15, (1911).
[4] Diener, *op. cit.*, p. 16; Pl. II, fig. 10, (1911).

*Productus* (*Marginifera bivius*, sp. nov. (Pl. 1, figs. 3, 3*b*).

There is one fairly well preserved pedicle-valve of a species of *Marginifera* which has a subquadrate outline with a hinge-line rather less than its width; the valve is strongly convex from back to front, somewhat flattened transversely in the anterior median portion but descending steeply on each side; near the umbo there is a very weak, broad, median depression; the umbo is large, prominent, high and incurved, with an umbonal angle of about 45°, and it descends suddenly on each side to the small, subtriangular, depressed, but slightly swollen and rather sharply marked off ears; the cardinal angles are subrectangular. There is a distinct, though small, cardinal area observable. The surface of the umbonal region is ornamented with numerous small, low, somewhat elongated pustules, arranged in irregular, rather close quincunxorder, and also with fine concentric, somewhat undulating, thread-like lines; on the lateral umbonal slopes and on the ears the pustules become upstanding, hollow tubular spines which are larger and more prominent on the ears; on the middle and anterior portions of the valve the pustules become more elongated and slender, forming recumbent spine-bases which are more widely spaced and are arranged in quincunx order in concentric bands with the fine thread-like concentric lines between them well developed over the whole surface; there are also minute pits or punctæ on the shell which are irregularly distributed amongst the pustules, but these may belong to an inner layer of the shell. The diductor scars which are small, flabellate, divergent and marked with coarse radial grooves are clearly seen where the shell has been broken away and extend about one-fifth or one-sixth the length of the valve.

*Dimensions.*

| | | |
|---|---|---|
| Length | | 28 mm. |
| Width | c. | 28 mm. |
| Height | | 14 mm. |

*Affinities.*—This specimen seems to be very similar to those from Kehsi Mansam which Diener[1] compared with *Str. horrescens*, De Vern., but the ears bear larger spines and are more developed in our example, and it does not appear possible to refer it to the European species *Str. horrescens* and it is more like *Productus* (*Spino-*

[1] Diener, *op. cit.*, p. 37; Pl. V, figs. 21, 22, (1911).

*marginifera kweichowensis*, Huang[1] (mut. mov.) from Southern China, so that we must regard it as a new species and attach to it the name *bivius*. Apart from the lower, broader and undistorted umbo our species appears to bear a considerable resemblance, to the Australian shell *Aulosteges ingens*, Hosking, particularly in its shape, presence of tubular spines on the ears and recumbent spines on the rest of the surface. *Aulosteges ingens*, Hosking,[2] from Western Australia is considered by its founder to be allied to the Himalayan form described by Diener as *A.* cf. *gigas*, Netschajew, and to *A. dalhousi*, Dav., as figured by Waagen; the latter species is put by Netschajew [3] in the genus *Strophalosia* in the same group as *Str. wangenheimi*, De Verneuil.

It is not improbable that the shell from Dong-quan, Indo-China, which Mansuy [4] figured as *Productust uberculatus*, Moll. mut. *orientalis* is identical with our species.

*Aulosteges* cf. *tibeticus*, Diener ? (Pl. 1, fig. 2).

The interior of a nearly perfect brachial valve may probably be ascribed to this Tibetan species,[5] of which the internal characters were stated by Diener to be unknown. For the valve has the characteristic shape of this species and a sharply geniculated margin. In our specimen there is a long, straight, projecting, cardinal process grooved along its length, and from its base a horizontal, rounded, cardinal ridge runs out at right angles to each lateral angle of the marginal ridge where the valve is geniculated; the outer edges of the channel which grooves the cardinal process are continued over the flattened interior of the valve as thin, straight, lateral ridges diverging anteriorly at an acute angle, and there is a long but lower and thinner median ridge or septum running down the channel of the cardinal process and continued forwards beyond its base for three parts the length of the disk. Over the rest of the disk there are more or less continuous, but sinuous, low, narrow, rounded, radial

[1] Huang, *op. cit.*, p. 60; Pl. V, figs. 12, 13, (1932).

[2] Hosking, *Journ. R. Soc. Western Australia*, XVII, p. 16; Pl. V, figs. 1*a-c*; Pl. VI, figs. 2*a-c*, (1930-31).

[3] Netschajew, *Mem. Com. Geol. Russ.*, N. S., Livr. 61, pp. 43, 55, (1911).

[4] Mansuy, *Mem. Surv. Geol. Indo-China*, V, Fasc. 4, p. 30; Pl. IV, fig. 6*a-c*, (1916).

[5] Diener, Himal. Foss., 1, Pt. 3, p. 35; Pl. V, figs. 3-6. Hamlet, *op. cit.*, p. 30; Pt. V, fig. 3, (1927-28).

ridges, 10–12 on each side, running out to the sudden geniculation which is marked by the above-mentioned, sharply raised marginal concentric ridge defining the edge of the disk, and they are continued over it as ribs to the margin of the valve. Between the median septum and the lateral ridges there is a pair of elongated muscle-scars.

Diener[1] has figured some fossils from Kehsi Mansam as referable to *Strophalosia costata*, Waagen,[2] of the Productus Limestones of the Salt Range, but we may doubt if this reference is correct, and they probably belong to the same species as our present brachial valve. Kayser's[3] figures of the interior of the brachial valve of the shell which he terms *Pr. nystianus*, De Kon. var. *lopingensis*, bear a great resemblance to our specimen, but no true species of *Productus* or *Marginifera* has a cardinal process or internal characters like it. Chao[4] appears to be fully justified in denying the identity of *Strophalosia poyangensis*, Kayser, with Diener's species *A. tibeticus*, as has been maintained by some authors. The internal characters of *A. medlicottianus* Waag.,[5] which Huang[6] identifies with *Str. poyangensis*, show many features similar to those in our specimen and suggest its reference to the genus *Aulosteges*.

*Dimensions*

| | |
|---|---|
| Width . . . . . . . . . | 15·5 mm. |
| Length . . . . . . . . . | 11·5 mm. |

*Chonetes* sp.

The species which Loczy[7] figured from the Carboniferous of China as *Chonetes pseudo-variolata*, Nikitin, is apparently represented by one imperfect specimen from the road to Möng Pawn. Chao's[8] figures of *Ch. latesinuata*, Schellw., seem to indicate a closely allied form. Diener[9] figures *Ch.* cf. *variolata*, D'Orb., from Namun,

[1] Diener, *Pal. Ind.*, N. S., Vol. III, p. 36; Pl. V, figs. 14-18, (1911).
[2] Waagen, *op. cit.*, p. 655; Pl. LXIII, figs. 7, 8; Pl. LXIV, fig. 1.
[3] Kayser in Richthofen's 'China,' IV, p. 187; Pl. XXVIII, figs. 3, 4, (1883). Chao, *op. cit.*, I, p. 153; Pl. XVI, figs. 8-12. (*Marg. lopingensis*), (1927).
[4] Chao, *op. cit.*, II, p. 73, (1928).
[5] Waagen, *op. cit.*, p. 663; Pl. LXII, figs. 4*a*, 4*c*.
[6] Huang, *op. cit.*, p. 66; Pl. IV, figs. 7-13; Pl. V, fig. 25, (1932).
[7] Loczy, Beitr. Pal. Stratigr. Result. Reise Graf Szechenyi in Ostasien, p. 73; text figs. 12*a-e*; Pl. III, figs. 8-12, (1898).
[8] Chao, *op. cit.*, II, p. 22; Pl. I, figs. 23-25; Pl. II, figs. 3-12; Pl. IV fig. 7, (1928).
[9] Diener, *op. cit.*, p. 52; Pl. VII, figs. 1*a-c*, (1911).

but it seems to be different to our specimen. Chao [1] refers Loczy's *Ch. pseudo-variolata* to *Ch. carbonifera*, Keys., but our specimen can hardly be referred to that species.

*Fenestella jabiensis*, Waagen and Pichl.

A well preserved small portion of a zoarium showing the poriferous face must be referred to *F. jabiensis*, Waag. and Pichl,[2] but in some respects it resembles Bassler's species *F. pulchradorsalis*[3] from Timor. There are 2–3 pores to each fenestrule, one being usually situated at the base of a dissepiment. The pores do not project into the fenestrules but lie well inside the edges of the branches. The fenestrules are narrower than the branches, sub-elliptical to oblong in shape and longer than wide. The carina of the branches bears small rather widely separated nodules. The dissepiments are short, depressed, much narrower than the branches but expand somewhat at their bases. Waagen's figures do not show the frequent occurrence of a pore at the bases of the dissepiments, but otherwise our specimen agrees in all essential features.

*Fenestella* sp.

A fragment of another zoarium on the same piece of rock from the same locality shows only the reverse face which is composed of a series of delicate, straight, regularly parallel branches ornamented with 3–4 fine longitudinal lines and connected by rather more slender horizontal smooth dissepiments set at regular intervals apart, not much swollen at their bases and not regularly alternating. The fenestrules are oblong and rectangular, of equal size and about $1\frac{1}{2}$ times to twice as long as wide. There are 8–9 fenestrules in a length of 5 mm. and 11–12 in the same width. The specific relations of this form are doubtful.

*Polypora* cf. *tranninhensis*, Mansuy.

A well preserved portion of a zoarium was collected by the author from this locality. It shows the poriferous face, and its characters appear to agree with those of a specimen figured by Diener[4] as *Polypora* cf. *biarmica*, Keys., from Namun, but the branches are not as wide as or wider than the fenestrules as is the

[1] Chao, *op. cit.*, II, p. 18; Pl. I, figs. 19-22; Pl. III, figs. 6-14; Pl. IV, fig. 6, (1928).
[2] Waagen and Pichl, *op. cit.*, p. 778; Pl. LXXXVIII, figs. 1, 2.
[3] Bassler, *op. cit.*, p. 74; Pl. 240 (16), figs. 10-13.
[4] Diener, *op. cit.*, p. 58; Pl. VII, fig. 23*a*, *b* (1911).

case in Stuckenberg's[1] figure of an example of *P. biarmica*, Keys., from the Upper Carboniferous of the Urals, and in this respect and in the fewer pores it more resembles *P. megastoma*, De Kon., as figured by Stuckenberg,[2] though it is not like the specimen from Namun which Diener[3] compared with that species. Waagen and Pichl[4] figure a species as *P. biarmica*, Keys., from the Salt Range, but it seems to be distinct from the Upper Carboniferous Russian form,[5] though their specimen as well as Diener's represents a species apparently agreeing in all respects with our zoarium. *P. tranninhensis*, Mansuy,[6] from Laos, which its author compares with *P. biarmica* is at any rate apparently indistinguishable from our form, and it may certainly be compared with it.

*Streblotrypa bassleri*, sp. nov. (Pl. 2, fig. 7).

A slender nearly straight cylindrical rod-like bryozoan shows 8–10 parallel, longitudinal, narrow, rounded ridges on its circumference, between which lie rows of small subcircular or oval, widely separated, equidistant zoœcial apertures, alternating in adjacent rows; below and longitudinally between the zoœcia are slightly depressed, elongated areas three to four times the length of the zoœcial apertures having two parallel lines of 8-10 minute pores (mesopores). This species is much like *Streblotrypa nicklesi*, Ulrich,[7] of the Chester group of Illinois, but is more nearly related to *Str. biserialis*, Bassler,[8] of the Permian of Timor, with which indeed it may be identical. But Bassler describes the zoœcial apertures as elongated-oval, instead of subcircular, and his figure shows fewer longitudinal rows of zoœcia on the stem, so that a different designation seems desirable for our Shan form. Our specimen from this locality measures about 1·5 mm. in diameter and is 7 mm. in length. The zoœcia are closer together and the pores between them fewer in number than in *Str. birmanica* above described from Htam Sang, while the longitudinal ridges are straight and continuous.

[1] Stuckenberg, *op. cit.*, p. 158; Pl. XXIII, fig. 1*a*, *b*, (1895).
[2] *Ibid.*, p. 163; Pl. XXIII, fig. 7*a*, *b*.
[3] Diener, *op. cit.*, p. 59; Pl. VII, fig. 24*a*, *b*, (1911).
[4] Waagen and Pichl, *op. cit.*, p. 791; Pl. XC, figs. 5-7.
[5] Tschernyschew and Stepanov, Faune Carb. Super. de la Terre du Roi Oscar, etc., *Mater. pour Géol. Russ.*, XXVII, p. 38; Pl. IV, fig. 7, (1916).
[6] Mansuy, *Mem. Surv. Geol. Indochine*, VII, Fasc. 1, p. 52; Pl. VI, figs. 4*a*, *b*, (1920).
[7] Ulrich, *op. cit.*, p. 667; Pl. LXXI, figs. 9, 9*a*-*c*, (1890).
[8] Bassler, *op. cit.*, p. 68; Pl. CCXXXIX (15), fig. 3, (1929).

***Rhabdomeson submurale***, sp. nov. (Pl. 2, fig. 13).

**Zoarium composed of slender, straight, hollow, cylindrical stems 1·5–2 mm. in diameter, rarely bifurcating, and bearing on the circumference 6–8 rows of relatively large subrhomboidal zooecia with oval or subcircular apertures, arranged in somewhat irregular diagonal lines, and surrounded by rather prominent thin walls bearing a ring of small, closely set, round, hollow granules with usually three larger ones (acanthopores) at the sides or one large one at the base.**

*Remarks*.—The large size and small number of the zooecial apertures and their indistinct diagonal arrangement recall the species from the Pennsylvanian of Texas which Moore has called *Rhombopora muralis*,[1] but the hollow stem of our species indicates its reference to the genus ***Rhabdomeson*** and suggests its closer relation to the supposed *Rh. rhombiferum* (Phill.) figured by Bassler,[2] though it is unlike the typical British form of that species.

*Michelinia* cf. *yunnanensis*, Reed.

There is one small, low, subhemispherical corallum in the collection. measuring 14 mm. in diameter and only 2–3 mm. in height. The corallites are very short and nearly all of the same size, 9–10 occurring across the face of the corallum; their margins are nodulated, the nodules corresponding with septal ridges in the deep calices. It seems to be allied to *Michelinia minima*, Stuck.,[3] and to *M. parasitica*, Phill.,[4] both of which are recorded from the Upper Carboniferous of the Urals, but the species which the present author described from the Permian of Yunnan as *M. yunnanensis*[5] may especially be compared. The American species *M. eugeneae*, White,[6] from the Drum limestone of Kansas, may also be allied. None of the Chinese species of this genus which Huang[7] and Yoh[8] have recently described are allied to our small form, but it is possible that Loczy's[9] *Favosites* cf. *jabiensis*, Waag. and Wentz., from Talishao, Yunnan, is identical.

[1] Moore, *op. cit.*, p. 141; Pl. 17, fig. 9.
[2] Bassler, *op. cit.*, p. 69; Pl. CCXXXVII (13), fig. 4
[3] Stuckenberg, *op. cit.*, p. 226; Pl. XIV, fig. 7, (1895).
[4] *Ibid.*, p. 118; Pl. XVIII, figs. 3*a*, *b*.
[5] Reed, *Pal. Ind.*, Vol. X, Mem. No. 1, p. 108; Pl. XI, figs. 1, 2, (1927).
[6] Sayre, *Bull. Univ. Kansas Sc.*, XIX, Pt. 2, No. 8, p. 85; Pl. 1, figs. 1, 2, (1930).
[7] Huang, *Palæont. Sinica*, Ser. B., VIII, Fasc. 2, pp. 92-103, (1932).
[8] Yoh and Huang, *ibid.*, Ser. B, VIII, Fasc. 1, pp. 21-24, (1932).
[9] Loczy, *op. cit.*, p. 123; Pl. V, figs. 27, 27*a*, *b*, (1898).

## CONCLUSIONS.

Though the general reference of these faunas (except that from Poila) to the Anthracolithic system is unquestionable, their precise stratigraphical horizons are somewhat difficult to fix, particularly in the absence of Foraminifera, for the detailed succession and relative ages of the members of the whole 'Anthracolithic system' (which includes the Productus Limestones) in the neighbouring regions of Indo-China have been based on their distribution.[1] The separation of the Uralian from the Permian in this system has always been more or less arbitrary and is still a matter of much difference of opinion, as Fromaget and others have recently observed, and some palæontologists would indeed consider the Uralian to be of Lower Permian age, but this question cannot be discussed here. The most complete succession in South-East Asia which has been described (*op. cit.*) is in Cammon (Laos) where the Moscovian, the Uralian and the Permian are divisible into twelve horizons, and there is stated to be a gradual passage upwards through the whole series, no clear demarcation being recognisable between the different stages or periods. It is naturally to this adjacent Indo-Chinese area that we may look for the closest agreement with the Anthracolithic beds of the Southern Shan States, but we have not sufficient evidence as yet to institute a close correlation, and the composition of the fauna appears to be different from any described by Mansuy or others from Indo-China, for few, if any, of the species seem to be common to the two areas. The feature of the fauna from the Southern Shan States is the large number of peculiar bryozoans, many of which are new species. These and other differences, however, may be due to special environment or to accidents of collecting rather than to important differences of age.

As regards the Northern Shan States the fauna from Kehsi Mansam described by Diener[2] resembles that of Htam Sang in many respects, while that from Namun[3] somewhat more closely resembles the Taung-gyi–Möng Pawn fauna collected by the author, and this fauna is apparently identical with that previously described by Diener[4] from Möng Pawn, the abundance of bryozoa

[1] Fromaget, *Bull. Surv. Geol. Indochine*, XIX, Fasc. 2, pp. 1-44, with two maps (1931).
[2] *Ibid.*, pp. 61-67 ; Pl. VI ; pp. 6-13.
[3] Diener, *op. cit.*, pp. 44-61 ; Pl. VII.
[4] *Ibid.*, pp. 61-67 ; Pl. VI ; pp. 6-13.

being a distinct feature and the slabs of rock being often true lumachellæ, as Diener remarked.

The two faunas of Htam Sang and of the Möng Pawn road in the Southern Shan States above described are seen to have somewhat different assemblages of species and probably belong to two horizons. The fauna from Htam Sang contains the typical Permian brachiopod *Lyttonia nobilis* as well as probably a few other Productus Limestone species, but its composition is unlike that of the typical Productus Limestones of the Salt Range, and it is noticeable that the common and typical species of the genus *Productus* occurring in that region are absent from it.

Grabau[1] states that

> 'The Asiatic Permian finds its most complete expression in South China where it begins with the *Tetrapora* fauna of the Chihsia, and this is followed by a series of faunæ......essentially that of the Middle Productus Limestone of the Salt Range; in it *Lyttonia* makes its first appearance.'

Huang [2] has recently attempted a detailed classification and correlation of the Permian of Southern China and puts the Uralian of European Russia below the Lower Productus Limestones of the Salt Range. We cannot fail to note that many of the species from the Southern Shan States show greater affinities with Upper Carboniferous forms than with Permian.

## APPENDIX.

### By STANLEY SMITH, M.A., D.Sc., F.G.S.

LOPHOPHYLLUM ORIENTALE, sp. nov. (Fig. 1, p. 130).

The small, simple corals which occur in considerable numbers at Htam Sang, Southern Shan States, can be referred to the genus *Lophophyllum*, Edwards and Haime.[3] They are closely related to *Cyathaxonia proliferum*, McChesney,[4] of the Pennsylvanian, Springfield, Illinois, 'very widely distributed throughout the Western States', U. S. A. and to *Lophophyllum* spp. described from the Permian of Southern China by T. K. Huang.[5] (Probably Diener's specimens from the Southern Shan States which he referred to as

[1] Grabau, *Bull. Geol. Soc. China*, XI, No. 3, p. 238, (1931).
[2] Huang, *Mem. Geol. Surv. China*, Ser. A, No. 10, pp. 109-112, (1932).
[3] Edwards and Haime, Mon. Pal. Foss., p. 349, (1851).
[4] McChesney, Desc. Pal. Foss., p. 75; Pl. II, figs. 1-3, (1860).
[5] Huang, *Palæont. Sinica*, Ser. B, VIII, pp. 22-32; Pl. I, (1932).

*Cyathaxonia*, sp. ind.,[1] belong to the new species from Htam Sang here described. F. R C. R.)

Genus : *Lophophyllum.*

*Lophophyllum*, Edwards and Haime, p. lxvi, (1850); 349, (1851).

*Genosyntypes.*—

*Lophophyllum konincki*, Edwards and Haime, p. 349; Pl. III, figs. 4, 4*a*, (1851), Carboniferous, Tournaisian, Tournai, Belgium.

*Lophophyllum dumonti*, Edwards and Haime, p. 350; Pl. III, figs. 3, 3*a*, (1851). Carboniferous, Tournaisian, Tournai, Belgium.

*Genolectotype.*—

*Lophophyllum konincki. See* Miller, p. 195, (1889).

*Diagnosis.*—Small, simple corals agreeing in most characters with *Zaphrentis*, but in which the counter septum dilates axially to form a stout columella.

*Remarks.*—Edwards and Haime[2] diagnosed their genus and gave as the genotype '*Lophophyllum konincki* nob.'. They did not, however, describe or figure this species until 1851, so that in the earlier work the species has no standing. Miller actually fixed the type when he quoted *L. konincki* as the genotype of *Lophophyllum*. Carruthers[3] makes *Lophophyllum konincki*, Edwards and Haime, conspecific with *Cyathaxonia tortuosa*, Michelin.[4] He considered that the type (or types) of *Lophophyllum konincki* represented an early growth stage of Michelin's species. Although he is probably right, his conclusion still requires further confirmation. *Cyathaxonia tortuosa* is a tall slender coral which in the ephebic stage has dissepiments, and the septa do not reach the columella. If the two are identical as Carruthers thinks and if it should be argued that *Cyathaxonia proliferum*, McChesney, and other corals which resemble it in not advancing beyond the *Lophophyllum konincki* stage cannot be retained in *Lophophyllum*, then these must be placed in the genus *Lophophyllidium*, Grabau,[5] founded upon *Cyathaxonia proliferum.*

[1] Diener, *op. cit.*, p. 67; Pl. VI, figs. 12, 13, (1911).
[2] *Op. cit.*, p. lxvi, (1850).
[3] Carruthers, *Geol. Mag.*, Dec. V, X, p. 50, (1913).
[4] Michelin, Icon. Zooph., p. 248; Pl. LIX, fig. 8, (1846).
[5] Grabau, *Palæont. Sinica*, Ser. B, No. 2, p. 98, (1928).

These corals, it may be pointed out, are in no way related to *Cyathaxonia cornu*, the genotype of *Cyathaxonia* which belongs to an entirely different group of Rugose corals.

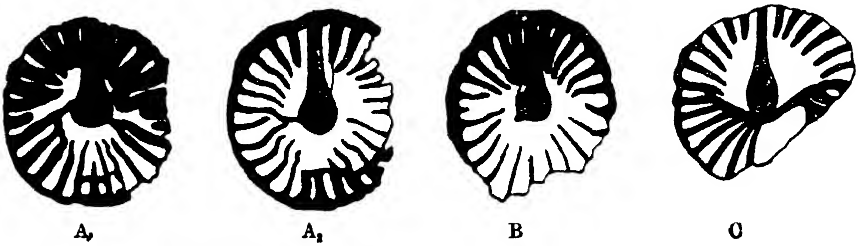


FIG. 1. *Lophophyllum orientale*, sp. nov.
A. Transverse section of corallum, 22 mm. in length. A 1 at 14 mm.; A 2 at 16·5 mm. (Slide 1).
B. Transverse section of corallum, 21 mm. in length. At 14 mm. (Slide 2).
C. Transverse section of corallum (Slide 3).
All from Htam Sang.

*Lophophyllum orientale*, sp. nov. (Fig. 1, A, B, C.)

*Lophophyllum proliferum*, McChesney, Jakowlew, pp. 9 14; Pl. I, figs. 1, 2, 4, 6, 7 and 8, (1903) (non *Lophophyllum proliferum*, McChesney, p. 75; Pl. II, figs. 1-3, (1860).

*Diagnosis.*—Slender *Lophophyllum* with the counter septum strongly dilated and expanded axially to form a moderately large columella. Major septa only are present.

*Description.*—The corallum is trochoid, and only slightly curved. The average height of the specimens from Htam Sang is 20 to 22·5 mm. and the diameter through the calice 7·5 to 10 mm. The calice is moderately deep and the inside tapers to a small floor occupied by the prominent columella. The sides of the corals are smooth, since they are only lightly striated longitudinally and feebly wrinkled. In many specimens, however, the epitheca has perished and the edges of the septa are exposed, giving the coral a strongly fluted appearance. There are usually 24 or 26 long major septa, but the minor septa are not developed. The cardinal septum is short, but the counter is much thicker than the rest of the septa and its axial edge is enlarged to form a stout columella, varying in its transverse section in different individuals, but attaining a diameter of 1·5 to 2 mm. The tabulæ are distant and slope down towards the periphery. There are no dissepiments. The lumen is in many cases completely or partially filled with stereome which masks the coral structures.

*Remarks.*—This Htam Sang form which occurs in considerable abundance appears to be specifically identical with the coral described from the Permian of Donez Basin by Jakowlew and is very closely allied to the species of *Lophophyllum* recently figured by Huang from the Mid-Permian of Southern China, particularly *L. zaphrentoides*, Huang[1].

*Lophophyllum orientale* differs from the American form *L. proliferum*, McChesney, judging from the figures of that coral by Huang[2] in the suppression of minor septa, its smaller columella and enlarged counter septum.

*Horizon and Locality.*—Anthracolithic, Htam Sang, Southern Shan States.

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[1] Huang, *op cit.*, p. 28; Pl. II, figs. 7, 8, (1932).
[2] Huang, *op cit.*, Pl. II, figs. 1*a*-1*d*, (1932).

## EXPLANATION OF PLATES.

PLATE 1, FIG. 1.—*Productus* (*Marginifera*) cf. *kweichowensis* Huang. × 2. Htam Sang.

" FIG. 2.—*Aulosteges* cf. *tibeticus*, Diener. Interior of brachial valve. × 2½. Near 24th milestone on Taung-gyi-Möng Pawn road.

" FIG. 3.—*Productus* (*Marginifera*) *bivius*, sp. nov. Pedicle-valve. × 1½. Near 24th milestone on Taung-gyi-Möng Pawn road.

" FIG. 3*a*.—*Productus* (*Marginifera*) *bivius*, sp. nov. Posterior view of same specimen. × 1½.

" FIG. 3*b*.—*Productus* (*Marginifera*) *bivius*, sp. nov. Portion of surface of shell of same specimen. × 4.

" FIG. 4.—*Squamularia duplex*, sp. nov. Complete specimen. Brachial valve view. × 2. Htam Sang.

" FIG. 4*a*.—*Squamularia duplex*, sp. nov. Complete specimen. Pedicle-valve view of same specimen. × 2.

" FIG. 4*b*.—*Squamularia duplex*, sp. nov. Complete specimen. Side view of same specimen. × 2.

" FIG. 4*c*.—*Squamularia duplex*, sp. nov. Complete specimen. Anterior marginal view of same specimen. × 2.

" FIG. 4*d*.—*Squamularia duplex*, sp. nov. Complete specimen. Portion of surface of same specimen. × 12.

" FIG. 5.—*Notothyris persimilis*, sp. nov. Complete specimen. Brachial valve view. × 2½. Htam Sang.

" FIG. 5*a*.—*Notothyris persimilis*, sp. nov. Complete specimen. Side view of same specimen. × 2½.

" FIG. 5*b*.—*Notothyris persimilis*, sp. nov. Complete specimen. Pedicle valve view of same specimen. × 2½.

" FIG. 5*c*.—*Notothyris persimilis*, sp. nov. Complete specimen. Anterior marginal view of same specimen. × 2½.

" FIG. 5*d*.—*Notothyris persimilis*, sp. nov. Complete specimen. Portion of surface of shell of same specimen. × 10.

" FIG. 6.—*Spirigerella praelonga*, Waagen, var. nov. *shanensis*. Complete specimen. Side view. × 2. Htam Sang.

" FIG. 6*a*.—*Spirigerella praeonga*, Waagen, var. nov. *shanensis*. Complete specimen. Anterior marginal view of same specimen. × 2.

" FIG. 6*b*.—*Spirigerella praelonga*, Waagen, var. nov. *shanensis*. Complete specimen. Pedicle-valve view of same specimen. × 2.

" FIG. 6*c*.—*Spirigerella praelonga*, Waagen, var. nov. *shanensis*. Complete specimen. Brachial valve view of same specimen. × 2.

" FIG. 6*d*.—*Spirigerella praelonga*, Waagen, var. nov. *shanensis*. Complete specimen. Portion of surface of shell of same specimen. × 8.

PLATE 1, FIG. 7.—*Spiriferina* (*Spiriferellina*) *shanensis*, sp. nov. Complete specimen. Brachial valve view. × 2½. Htam Sang.

" FIG. 7*a*.—*Spiriferina* (*Spiriferellina*) *shanensis*, sp. nov. Complete specimen. Pedicle-valve view of same specimen. × 2½.

" FIG. 7*b*.—*Spiriferina* (*Spiriferellina*) *shanensis*, sp. nov. Complete specimen. Anterior marginal view of same specimen. × 2½.

" FIG. 7*c*.—*Spiriferina* (*Spiriferellina*) *shanensis*, sp. nov. Complete specimen. Side view of same specimen. × 2½.

" FIG. 8.—*Spiriferina* (*Reticulariina*) *conquisita*, sp. nov. Brachial valve view. × 2½. Htam Sang.

" FIG. 9.—*Spiriferina* (*Reticulariina*) *conquisita*, sp. nov. Another specimen. Brachial valve. × 2½. Htam Sang (A. 534).

PLATE 2, FIG. 1.—*Fenestella multinodulosa*, sp. nov. Portion of zoarium· × 15. Htam Sang. (A. 534).

" FIG. 1*a*.—*Fenestella multinodulosa*, sp. nov. Zoarium of same specimen. × 3.

" FIG. 2.—*Fenestella gemmata*, sp. nov. Portion of zoarium. × 12. Htam Sang.

" FIG. 3.—*Rhabdomeson shanense*, sp. nov. Portion of stem. × 12. Htam Sang.

" FIG. 4.—*Fistulipora servata*, sp. nov. Portion of surface of zoarium. × 10. Htam Sang.

" FIG. 4*a*.—*Fistulipora servata*, sp. nov. Zoarium of same specimen. nat. size.

" FIG. 5.—*Polypora discreta*, sp. nov. Zoarium showing dissepiments. × 2. Htam Sang.

" FIG. 5*a*.—*Polypora discreta*, sp. nov. Another part of same zoarium without dissepiments. × 2.

" FIG. 5*b*.—*Polypora discreta*, sp. nov. Portion of branches of same specimen. × 10.

" FIG. 6.—*Michelinia dieneri*, sp. nov. Complete corallum. × 2. Htam Sang.

" FIG. 6*a*.—*Michelinia dieneri*, sp. nov. Portion of same corallum. × 5.

" FIG. 7.—*Streblotrypa bassleri*, sp. nov. Portion of stem. × 15. Near 24th milestone on road from Taung-gyi to Möng Pawn.

" FIG. 8.—*Streblotrypa bassleri*, sp. nov. Portion of another stem. × 20. Htam Sang.

" FIG. 9.—*Rhombopora circumcincta*, sp. nov. Zoarium. × 2. Htam Sang. (A. 534).

" FIG. 9*a*.—*Rhombopora circumcincta*, sp. nov. Portion of same specimen. × 12.

PLATE 2, FIG. 10.—*Rhombopora circumcincta*, sp. nov. Portion of another specimen. × 20. Htam Sang.

" FIG. 11.—*Polypora koninckiana*, Waagen and Pichl, var. nov. *postera*. Zoarium. × 1½. Htam Sang.

" FIG. 11*a*.—*Polypora koninckiana*, Waagen and Pichl, var. nov. *postera*. Portion of same specimen. × 6.

" FIG. 12.—*Rhombopora virgula*, sp. nov. Portion of stem. × 15. Htam Sang.

" FIG. 13.—*Rhabdomeson submurale*, sp. nov. Portion of stem. × 15. Near 24h milestone on road from Taung-gyi to Möng Pawn.

" FIG. 14.—*Streblotrypa birmanica*, sp. nov. Portion of stem. × 15. Htam Sang. (A. 534).

" FIG. 15.—*Strophalosia* sp. Brachial valve. × 2. Htam Sang.

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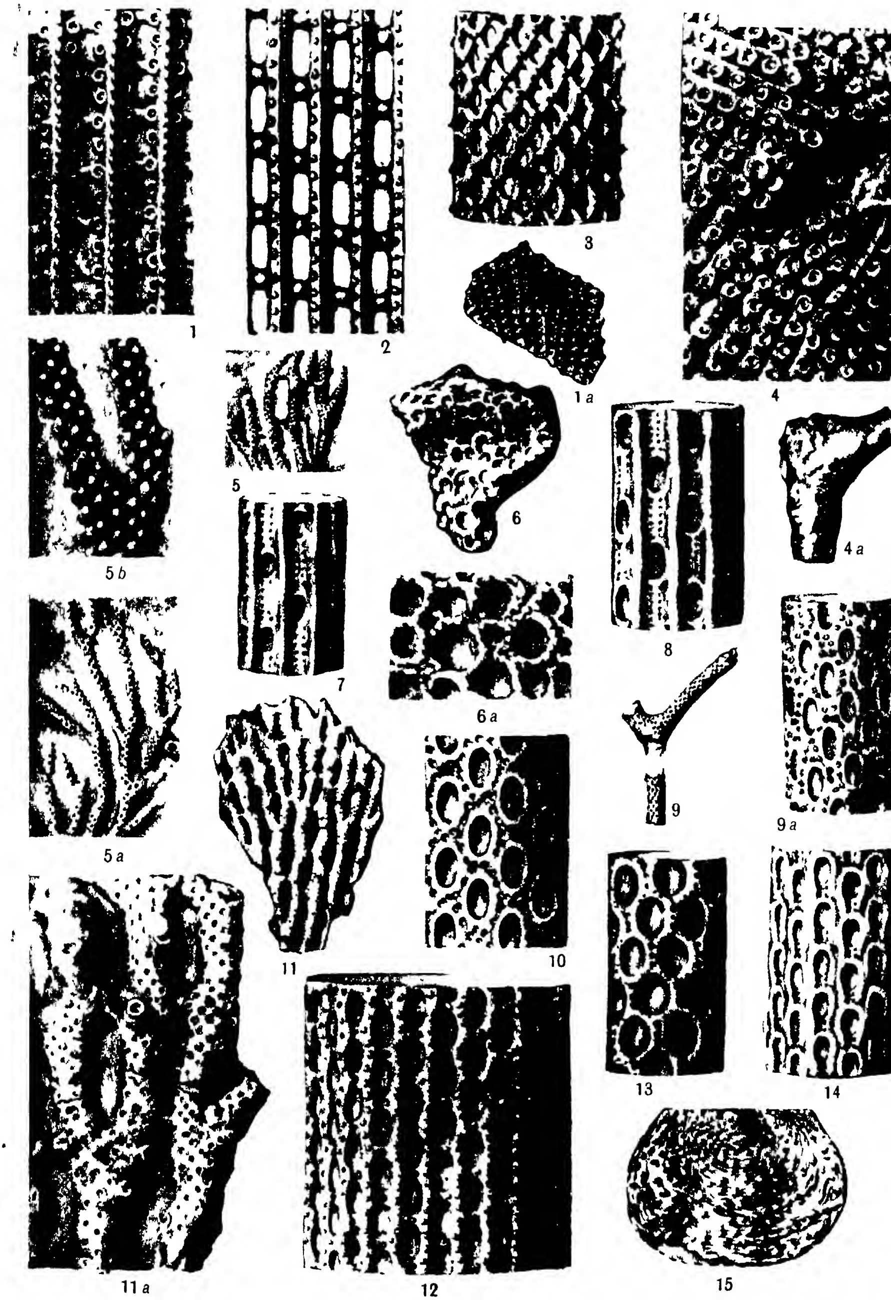
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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1933. [December

# Geological Reconnaissance in the Southern Shan States.

By J. Coggin Brown, O.B.E., D.Sc., *Superintendent*, and V. P. Sondhi, M.Sc., F.G.S., *Assistant Superintendent*, *Geological Survey of India*. (With Plates 3-5.)

## CONTENTS.

## TAUNGGYI TO HOPŌNG (sheet 93 H/1).

For ten miles east of Taunggyi, as measured along the main road, Plateau Limestones continue. They build the precipitous crags and the ridge that faces a Lower Palæozoic inlier on the west and overshadows Taunggyi on the east, in consequence of which the road has to make a detour of some miles to the south before continuing in its normal direction. These crags have a general easterly dip with a few minor undulations down to the Hopōng plain at Pā-leng, ten miles from Taunggyi.

The rocks seen are all typical representatives of the lower division of the Plateau Limestone, sometimes grey brecciated dolomites friable enough to be kicked to powder; oftener, harder, greyish white, recemented material with a deceptive sandy appearance and occasionally banded with pink. Travertine and secondary limestones are of common occurrence over the flat ground between the first and second steep descents, *i.e.*, between miles 5 and 8.

Before joining the plain at Pā-leng, another line of sharp crags showing dip-slopes to the east is passed, and the highest of these, 4,643 feet, has a well-known sacred cave on its southern spur.

Just east of Pā-leng the road touches the southern edge of an inlier of the Lower Palæozoics, poorly exposed in a few places between this village and Hopōng. Along their junction with the older rocks the Plateau Limestones are fossiliferous, showing sections of crinoidal stems, brachiopods and corals. A cap of similar limestone rests unconformably upon the older rocks about four miles N. N. W. of Hopōng. The latter rocks that build up the greater portion of the ridge here, dip steeply to the east and the Plateau Limestone, showing gentle dips to the north-east, forms the crest of the ridge with peaks of over 5,000 feet height.

## TRAVERSE SOUTH OF HOPŌNG (sheets 93 H/1 and H/2).

Hopōng lies at an elevation of 3,600 feet at the head of the narrow plain of the Nam Tamhpak, a stream which flows to the south through the small Shan States of Namhkok, Nawngwawn, Wan yin and Hsahtung, for 86 miles before it turns east to enter the Nam Pawn. Along this portion of its course, it forms the northern boundary between the Federated Shan States and Kantarawadi, one of the independent states of Karenni.

A traverse was made down this valley from Hopōng to Namhkok, a distance of 13 miles. Around Hopōng the character of the country, although it is underlain by Lower Palæozoic rocks, recalls the downs of Thamakan, between Kalaw and Taunggyi, in its rounded grassy outlines, bamboo groves, lines of giant aloes and occasional banyan trees, but the valley is hemmed in to the north-east and west by limestone hills. For the greater part of the distance traversed, the road lies on the alluvium of the plain or on the lower flanks of the eastern foot-hills. In the first mile or two, tufa is abundant in the alluvium. Although exposures are few and far between, there is little doubt that for five or six miles Plateau Limestone forms both walls of the valley; thus at the sixth mile tabular, westerly dipping bands can be seen as steep scarps.

**Plateau Limestone overlies the Lower Palæozoic rocks of the valley floor.**

The isolated hill of Loi Tang, which rises from the plain to the west of the eighth mile, has a thick capping of Plateau Limestone, probably of the younger division, and may be entirely built of this rock.

Further south, however, a change becomes apparent and while the limestones continue in the western hills, the eastern ones lose their rugged character and become more rounded, the *terra rossa* giving place at the same time to sandy, light reddish brown soils. The character of the vegetation alters, scattered pines soon appear and increase at the expense of the other trees until, as in the case of the 4,010 ridge south of Namhkok, they become pure pine forests.

**A change takes place in the eastern wall.**

Between miles 11·7 and 12 there are poor outcrops of much weathered and altered brown, red-stained shales and light-coloured sandstones. These have undergone surface changes analogous to lateritisation with the production of limonitic iron ore in places. No fossils were found, but the rocks themselves and the character of the country generally strongly recall the Namhsim group of the Northern Shan States.

**Shales and sandstones about mile 12.**

To the east of Namhkok, however, and within two miles of the town, are fantastic peaks and great chimneys of limestone again; outlying spurs of the Loi Mai range, the divide between the Nam Tamhpak and the Nam Pawn.

### HOPŌNG TO HTAMSĀNG (sheets 93 H/1 and H/5).

The higher ground east of Hopōng, where the road crosses it, has no well marked direction nor individuality for it consists, at any rate in this latitude, of a series of valleys of enclosed drainage, the winding rims of which give rise to a confused topography. Further south the development of a single ridge with peaks of over 8,000 feet in altitude, forming the boundary between the Hopōng and Namhkok States on the west and Möng Pawn on the east, seems to betoken a change in lithological composition.

Ascending through this area, winding around the spurs or zig-zagging across them, no rocks were seen except one or other of the many varieties of the Lower Plateau Limestone, until a minor crest is crossed at mile 20-7 where sandy shales follow brecciated dolomite. These continue to a point between miles 21-2 and 21-3. Near mile 22-3 there is a cauldron valley with limestone peaks around it and craggy outcrops continue at intervals to the crest at 22-7. Here there is a change and limestones are replaced by brown-grey and white, sandy shales.

**Fossiliferous Upper Plateau Limestones.**

Beyond these shaly outcrops at mile 23-2 occurs the first of the fossiliferous localities of the upper division of the Plateau Limestone, the organic remains from which enabled Diener to prove its Permo-Carboniferous age.[1] Middlemiss[2] was the first to obtain fossils in this neighbourhood and though it is not possible exactly to determine the different localities he mentions, his descriptions of the rocks themselves cannot be improved upon and for this reason are summarised below. The conversion of the rough cart track which he traversed in 1898 into a modern motor road has destroyed the utility of his distance points as a means of identification.

After describing how crushed and powdery dolomites with an irregular but high dip are followed by westerly dipping concretionary limestones, replaced in their turn by grey shales and interbedded concretionary limestones and marls, dipping east at 30° to 40°, Middlemiss describes how in these rocks, between miles 20-5 and 20-6, he first found fossils (localities 1 and 2). They made their appearance on the weathered surface in the form of corals, crinoid stems and brachiopods (chiefly *Athyris* sp.). The fossiliferous zones are generally either thinner banded, semi-concretionary limestones

[1] *Pal. Ind.*, N. S., Vol. III, Mem. No. 4, pp. 61-67, (1911).
[2] *Gen. Rep. Geol. Surv. Ind.*, 1899-1900, pp. 137-138, (1900).

in the vicinity of shales, or shaly or marly layers. Crossing the little pass at milestone 21 a course of dark grey fissile shales is found dipping at 30° to 40° to the east, weathering a pale buff or khaki colour with one or two thin quartzitic and somewhat calcareous layers. Descending now regularly towards Htamsāng, past milestone 22 till near 23 miles 5 furlongs a fine section of thin-bedded, concretionary-tabular bryozoan limestones with the usual interbedded marly layers, all packed with bryozoa, corals and brachiopods is found still dipping east (Middlemiss' locality 3*a*).

Again at milestone 24 similar rocks contained an abundance of fossils; amongst the brachiopods found in crops on the rain-loosened surface of the weathered shales, being several species of *Athyris* cf. *roysii* and *Spirigerella* cf. *derbyi* together with a quantity of *Chonetes grandicostata* and a few specimens of *Spiriferina cristata*, all characteristic of the Middle Productus Limestone of the Salt Range.

As measured along the road to-day, the places in which the best exposures of the bryozoan limestones occur are at miles 23-7 and 24-1 on the roadside. From representative collections made at these localities, Dr. F. R. C. Reed has identified the fossils listed in his paper on the Anthracolithic fauna of the Southern Shan States.[1]

Htamsāng Rest House is situated at mile 25-4 and around it and the village further west there are abundant rocky outcrops of the Lower Plateau Limestone protruding through the soil cap in all directions.

The road continues to descend to a natural bridge between miles 25-5 and 25-6 which Middlemiss termed 'a covering-in of the stream-bed, a limestone bridge left like a snow bridge spanning the chasm'. A short distance down-stream, at the bottom of the western wall of the gorge, is the entrance to a series of large and extensive caves carved out of the crushed, greyish white dolomite cliff. The road slowly ascends to the north-east and after a sharp turn to the east leaves the lower dolomites about mile 27½ to meet the tabular, greyish-black Permo-Carboniferous limestones and calcareous shales again which continue to the top of the ridge at mile 28-3. Somewhere about here Middlemiss found his fossil locality No. 5 from which he obtained *Spirifer musakhelensis*, *Productus* of

[1] *Rec. Geol. Surv. Ind.*, LXVII, pp. 83-134, (1933).

*indicus*, *Spiriferina cristata*, and a large number of *Chonetes* sp. among which are *Ch. grandicosta* and *Ch. dichotoma*—all eminently characteristic of the Middle Productus Limestone.[1]

A large collection was made at the crest by us and Dr. Reed has identified the species listed in the paper referred to above.[2]

## HTAMSĀNG TO MÖNG PAWN (sheet 93 H/5).

Ordovician rocks at mile 33-4.

After leaving the crest of the ridge with its richly fossiliferous, tabular Permo-Carboniferous limestones at mile 28-3, the road commences its winding descent to the Möng Pawn plain at mile 37-2, and about mile 36-5 again encounters fossiliferous Permo-Carboniferous strata which here border the plain. Between these two exposures there is a series of rocks consisting in the main of greenish grey shales, sandy shales and purple mudstones with less frequent sandstones and a solitary band of limestone. From these rocks C. S. Middlemiss in 1898 [3] obtained an impression of part of a trilobite, a gastropod, and ill-preserved cast of a portion of a *Nautilus* and some indistinct vermicular markings, but they failed to yield any fossils as a result of Dr. Coggin Brown's earlier examination. He pointed out then that the evidence, scanty as it is, points to the series being older than the Plateau Limestones, while lithologically, especially in the presence of fine-grained sandstones, it appeared to have affinities with the Namhsim (Silurian) beds of the Northern States. It was also stated that this was merely a tentative opinion and that the question would not be settled until more extended search than he was able to devote to them, at that time, had revealed a larger fauna in these beds.

An opportunity for a re-examination occurred in February, 1932, when we succeeded in finding fossil-bearing layers in both purple slates and tough brown mudstones at mile 33-4, which contain small brachiopods (mainly *Orthis* sp.), a few cystidean plates, bryozoa (including *Phylloporina* sp.), pieces of small trilobites and fragments of other fossil remains. *Phylloporina* is a bryozoan ranging from Ordovician to Silurian, but the only species hitherto described from the Shan States is *Phylloporina orientalis*, Reed, from the Lower Naungkangyi stage. The fauna as a whole, indeed,

[1] *Gen. Rep. Geol. Surv. Ind.*, 1899-1900, p. 138, (1900).
[2] *Rec. Geol. Surv. Ind.*, LXVII, pp. 85-86, (1933).
[3] *Loc. cit.*, p. 139.

indicates one of the Naungkangyi horizons and the probability now is that the whole sequence here referred to is of Ordovician age.

The fossiliferous limestones edging the Möng Pawn plain.

Abundant specimens of *Athyris* sp. and other brachiopoda may be obtained from the Plateau Limestone near the Möng Pawn plain by following the short cut which leads down to the river from the main road. Here they are weathered out in almost perfect preservation and occur in the clay on the sides of the foot path. The fresh sections of the limestone exposed in the road cuttings offer no opportunities for collection.

The Permo-Carboniferous age of these and similar limestones is uncertain.

In connection with this and other fossiliferous localities in the same rocks of the Htamsāng-Mòng Pawn neighbourhood, which have been consistently referred to as Permo-Carboniferous following Diener's determination,[1] it is necessary to note that Dr. Cowper Reed, who has seen a few selected specimens, does not think that there is any evidence for the Salt Range Productus Limestone fauna amongst them. As it has been customary hitherto to regard all these Shan States Permo-Carboniferous forms as more or less characteristic of, or nearly related to, those found in the Middle Productus Limestone of the Salt Range, the necessity for an expert opinion on the large collections which have been made by us in the last two years is evident. These collections are large, varied, and in excellent preservation, and are far in advance in these respects on any others previously made in the Shan States by earlier workers.[2]

## MÖNG PAWN TO LOI-SAMHPU PASS (sheets 93 H/5 and H/9).

An unfossiliferous sandy series builds the western flank of the Loi-Samhpu.

In the earlier report[3] the rock sequence which builds the western flank of the Loi-Samhpu range has been described as a sandy series consisting in the main of soft, fine-grained, fawn or brownish grey sandstones alternating with sandy shales. No fossils at that time were found to occur in them and further

[1] 'Anthracolithic Fossils of the Shan States', *Pal. Ind.*, New Series, Vol. III, Mem. No. 4, (1911).

[2] Since this paragraph was written the results of Dr. Reed's examination of these fossils have been received and published in Part 1 of this volume of the *Records*. Dr. Reed shows that these fossils are 'Anthracolithic' in age—Ed.

[3] *Rec. Geol. Surv. Ind.*, Vol. LXVI, Pt. I, p. 99, (1932).

intensive searches have again failed to discover any traces of organic remains.

Alleged galena occurrence in the Loi-Samhpu.

A few years ago, a prospecting license was granted over an area which embraced two miles of the crest of the Loi-Samphu range, including peak 6,091, extending almost down to the Hawngmakka *chaung* on the west and to the villages of Tawngnaü and Pānglōng on the east. It is reported that the licensee got into financial difficulties and absconded. The area has not been examined in detail but specimens of galena, alleged to come from it, have been obtained.

## LOI-SAMHPU PASS TO LOILEM (sheet 93 H/9).

Unfossiliferous limestones forms the higher eastern flank of the Loi-Samhpu.

In the same way the hard, slaty, grey or greyish blue limestones with occasional patches and streaks of a brown shale, forming both sides of the pass which leads the road across the Loi-Samhpu, at mile 49-7 from Taunggyi, have failed to yield fossils. The strike at the summit is approximately north and south and dip easterly at 45°. Beyond these exposures of limestone and as far as mile 51-5, there are alternations of splintery, slaty blue and slabby limestones with sandy mudstones, perhaps derived from impure calcareous bands. The strike at this point has swung round to N. N. E.–S. S. W., but the high easterly dips continue. About here highly cleaved and contorted light greenish grey and purple slates appear, the latter varieties continuing down past mile 51-6, where the dip changes to the south-west, only to revert to this prevailing easterly direction once more within a few yards.

The road crosses the strike of the limestones again at mile 52-1 and they are repeated after a blank patch at mile 52-3, where they are followed by bleached sandy purple shales. These rocks have been exceedingly disturbed and continue, though not in continuous outcrops, beyond the bottom of the hill as far as mile 53-3½.

In the earlier report it was stated that at mile 53-5, an area studded with small pot-holes is entered and that good exposures of limestones are visible on the southern side of the valley, which belong rather to the lithological types met with to the east of Loilem than to those which form the upper part of the Loi-Samhpu range.

This opinion revived abundant confirmation during the present season's work, for at mile 54-1 a band of dark carbonaceous shale

was found containing abundant specimens of *Monograptus*, the species of which appear identical with those from the Panghkawkwo graptolite bed. The dip of the shale is to the S. S. E. (For the benefit of future collectors it may be pointed out that the best specimens are obtainable on the western approach of bridge 2/55.)

**The Panghkawkwo graptolite bed was found to the west of Loilem.**

Poor exposures of shales between miles 55-1 and 55-2, usually in brown stained, greyish varieties yielded a lamellibranch and a few small brachiopods. These shales correspond with the mudstones found by Sondhi between miles 59-1 and 59-2.

At mile 55-5, although there are no rocks *in situ*, pieces of carbonaceous shales from the rain-washed detritus of the roadside were found to contain *Diplograptus* and other forms.

The best exposures of limestone on the west of Loilem (mile 57-5) are at mile 56-3, where pink, phacoidal varieties occur, identical with those above the Panghkawkwo graptolite bed. The dip here is to the south-east at about 40°. At Loilem itself, elevation 4,200 feet, there are no exposures, the rocks being masked under a thick mantle of residual soils. On both sides of this however, the Silurian limestone can be seen outcropping on the hillsides while the extraordinary number of little cauldron valleys in the neighbourhood, seventy or eighty of which exist within a radius of three miles to the north-east and south-west, prove its presence in the immediate vicinity.

**Silurian limestone exposures near Loilem itself.**

## LOILEM TO WĀN PONG[1] (sheet 93 H/9).

In the earlier report the occurrence of the Silurian coral *Palaeocyclus?* sp. was recorded from the pale purple mudstones which are found in poor exposures of the roadside cuttings about miles 58-5 to 58-7 just beyond Loilem. The first exposures of phacoidal limestones, usually of pink and purple colours, occur at the spillway of the Loilem lake, a large and picturesque sheet of water which has been brought into existence by means of a dam across a valley of enclosed drainage just above its sink-hole. From three separate

**New fossil localities in Silurian rocks near Loilem.**

[1] In the earlier report Dr. Coggin Brown identified Wān Pong with Bamping, the most easterly point reached by C. S. Middlemiss in his traverses of the Southern Shan States in 1898. This is incorrect. Bamping is the modern Bampon, a place in Mongnai State, ten miles west of the capital, and situated about 20° 30′ : 97° 47′ on sheet 93 H/15.

bands of brown mudstones which dip E. S. E. between miles 59·1 and 59·2, Sondhi made a small collection of fossils which will, when determined, assist in fixing the exact age of these beds. They are strongly folded and high dips both to the E. S. E. and W. S. W. have been recorded. The main limestone outcrops start between 59·2 and 59·3, dipping generally to the west or north-west, underlaid at 60·3½ by the graptolite beds of Panghkawkwo.

Types of Silurian limestone.

It may be recalled here that the commoner limestone types are hard, very fine-grained, compact rocks of various shades of light and dark grey which break with a splintery fracture. The uniform character of the groundmass is deceptive, for on weathering wavy layers become prominent giving rise to a characteristic large scale cellular or polygonal-patterned surface. Pink, green and purple varieties are rarer and occasionally the rocks are well-banded in layers of alternating colours.

The Panghkawkwo graptolite bed.

The graptolite beds are white or greyish white fissile shales often with dark grey laminæ and more rarely brown and light purple when they develop a thicker bedding and are not so easily split. In places they are severely crushed and folded but the general strike is N. 15° E. and the dip westerly at 65°. Provisional determinations by Miss G. L. Elles refer the specimens to *Climacograptus* sp. and *Monograptus sedgwicki* or *priodon*. Two horizons appear to be represented and the present season's collections should finally settle this point. The bed is believed to be not lower than Upper Valentian while it might be higher Salopian.

The Upper Naungkangyi purple beds.

About mile 60·4 where the graptolite bed ends, there are no continuous outcrops but such as do exist betoken a disturbed contact, the former dipping westerly and the underlying purple beds easterly. These beds are dark purple mudstones, often nodular, generally bleached and containing crinoid rings and crushed fragmentary fossils of Upper Naungkangyi age. Their dip changes rapidly from vertical to both easterly and westerly in a short distance.

Repetitions of the Panghkawkwo sequence.

The purple beds end in a small stream bed at mile 60·5 and are followed by black and white sandy shales with *Monograptus* similar to the Panghkawkwo varieties. Continuing to 60·6 they, in their turn, are followed by overlying limestone bands dipping to the

E. S. E. and identical lithologically with the ones found below Panghkawkwo.

At mile 61-1, the highest point is reached and the road turns to the north (and later to the east) as it zigzags down past mile 65 on to gently sloping ground which leads on to Wān Pong at mile 69. From the top to a point near mile 63-7 such rock exposures as are visible consist of repetitions of the same types. Although limestones are the prevailing rocks, outcrops of graptolite beds were also found, an advance on the previous observations and a proof that the whole of this part of the country is a closely packed series of folds in rocks of Silurian and Ordovician age. Details of the more important isolated exposures are given below :—

Details of the more important exposures.

Just beyond mile 60-7, the limestones are followed by hard, cleaved, carbonaceous and soft, faded purple shales which contain poor specimens of graptolites and fragments of trilobites.

Phacoidal limestones of normal types then occur which at mile 61 dip E. S. E. but between 61-3 and 61-4 this changes over to the W. N. W. At mile 62, an interbedded band of calcareous shale, again of a purplish colour, dips W. N. W. and is followed by limestone.

Between 62-63 and 62-5 the visible rocks appear to be duplications of the Panghkawkwo graptolite bed. Near mile 63, the limestones give place to pale-brown mudstones, not unlike those described from about mile 59-1, near Loilem, but they are followed immediately by limestone again, dipping W. N. W.

A large bluff of well banded, coarse honeycomb-weathered limestone hangs over the road at mile 63-6. From 63-7 to 64, bands of light, indurated shales, with thin layers of darker colours, occasionally passing into bleached carbonaceous shales, carry abundant graptolites in a poor state of preservation. The decomposition undergone by these rocks in suitable positions is impressive and upwards of 30 feet of variegated clay overlies them *in situ* in some of the cuttings. Interbedded bands of slaty blue-grey limestones with thin seams of siderite become commoner further east and between miles 64-1 and 64-2, limestones alone were seen. The latter continue at intervals to mile 64-7 where there are further occurrences of sandy graptolite-bearing shales, followed by more outcrops of limestone up to mile 65.

Here a complete change in topography takes place. The broad belt of elevated country, composed mainly of alternating infolded bands of limestones and shales and seamed with lines of small sink-holes along the strike of the thicker limestone horizons, gives place to lower ridges, divided by small permanent streams, which wind down to the Nam Teng, or disappear underground as soon as the edge of the great spread of Plateau Limestone is reached six or seven miles further east.

**A remarkable morphological change takes place at mile 65.**

At mile 65 the road turns to the east and south-east around the headwaters of one of these streams, the course of which is marked by a narrow stretch of paddy cultivation to which its alluvium is devoted. It then continues along the low ridge separating this valley from the one to the north in which the Nawngpawn lies.

Striking as this change of topography is, it is no less remarkable than the lithological variation which is responsible for it, for beyond mile 65, the limestones completely disappear and a new sequence of rocks makes its appearance. Thick soil buries all outcrops until mile 66-6 where pale brown, marly mudstones are found in poor exposures, interbedded with greyish white papery shales. The mudstones break up into small roughly spherical-shaped fragments and contain casts of the rings of small broken crinoid stems.

**It is due to a change in the lithology.**

After a short break in the sequence, they are followed near mile 67 by fine-grained sandstones of dark tints, sandy shales and thin bands of bleached purple mudstones, again with infrequent crinoid remains. Nā-pōk village is passed at 67-2 and between miles 67-5 and 67-6 there is one small outcrop of felspathic sandstone. More sandstones and shales occur between this point and mile 68, while from here to 68-4 there are practically continuous sandstone outcrops. Shales appear again between 68-4 and 68-5 and beyond these the rocks are entirely hidden, with the exception of a final exposure of light shales and mudstones at mile 69, on the western edge of the Wān Pong plain.

**A predominantly sandy series between mile 67 and Wān Pong.**

The best examples of the marly mudstones and shales in this section are at bridge 3/69, just beyond mile 68-4, where they are greatly folded and strike E. N. E.–W. S. W. The most typical sandstones occur at bridge 2/69, at mile 68-3, where they are white,

soft and cleaved. A thin band of bleached carbonaceous shale is found in the sandstones just before the bridge is reached.

Now the Lower Namhsim stage of the Northern Shan States is essentially an arenaceous one, the whole of the beds are of a sandy nature, sometimes very coarse in texture and elsewhere fine-grained and compact, hard and splintery. They also attain great thicknesses up to at least 2,000 feet in places, and occasionally have beds of coarse conglomerate at the base. Fossils are naturally rare in such rocks. Yet they do occur in the softer, finer-grained varieties and are sufficiently well-known to make the identification there as homotaxial with the Wenlock or Middle Silurian a positive matter. Until fossils are found in the rocks under description, it is unsafe to make comparisons and all that can be stated at present is that lithologically, and especially in their common strongly felspathic character, there is much resemblance between them.

**Possible Silurian correlation of the sandy series.**

## MR. SONDHI'S TRAVERSES FROM LOILEM (sheet 93 H/9).

Mr. Sondhi made a traverse from Loilem to the east, joining the main road again, which here makes a wide detour to the south, between miles 63 and 64.

For the first half mile there are no exposures visible beneath the prevailing light brown soil. After this limestone crops out as a light green rock, sheared, phacoidal and platy, in which the individual phacoids are up to two inches in length, one inch wide, and a quarter of an inch thick and separated by shining black films. Further to the east pinkish brown limestones occur and contain two bands of mudstone, similar to those found between miles 59-1 and 59-2, on the road and from which small brachiopods were obtained. These limestones are succeeded by a series of mudstones which are rarely exposed, but near the top of the first ridge, limestone is again met with as a chocolate-coloured rock, interbedded with various phacoidal varieties. These continue on the descent to the main road. At several places in the interbedded mudstones, traces of organic remains, particularly crinoid stems, are present.

**A series of interbedded limestones and mudstones.**

On another excursion further north still, Sondhi ascended the valley of the southerly flowing stream which passes Ho-hkai (a village two miles north of Loilem) and rises in Loi Lang (5,608 feet). Red mudstones with fragmentary fossils probably of Naung-

kangyi age occur on both sides of the valley. Ascending from it to the east there is an interbedded limestone band which, striking north, forms the summit of the mountain but the whole of the main southerly trending spur from Loi Lang is composed of the same mudstones with cystid plates, crinoid stems and fragmentary brachiopods. A narrow quartz vein was traced for about half a mile on the adjoining spur to the west.

Loi Lang is built of Naungkangyi mudstones capped by a limestone band.

## TRAVERSE TO THE NORTH OF LOILEM (sheets 93 H/9 and 93 G/12).

A traverse was made from Loilem for 13 miles to the north, following the course of the upper portion of the Nam Pawn before it breaks through the high boundary range (the Loi Samhpu) on the west, to resume its southerly direction through the centre of the State of Möng Pawn.

The valleys appear to have been the site of an old Pleistocene lake, for thick pebble beds and clays are seen in the side streams, especially near Wān-In, where the pebbles and boulders consist chiefly of vein quartz. Panning tests, however, failed to reveal the presence of gold; indeed, there was surprisingly little concentrate of any kind obtainable.

Remains of Pleistocene lacustrine deposits.

Exposures of solid rock are very infrequent as the road follows either the valley floor or the thick soil-covered flanks of the lower foot hills on the west, south of Pānglōng—6 miles 7 furlongs north of Loilem, and on the east, north of that place.

About mile 11 there are poor exposures of weathered purple mudstones containing traces of fossil fragments similar to those found by Mr. Sondhi on the spurs of Loi Lang (5,608 feet) further south. At the outcrops these rocks have undergone profound superficial changes and are converted into impure iron-ores.

Mudstones at the 11th mile.

They have evidently been used as a source of metallic iron by the Shans in times past, as slags are abundant hereabouts and are used by the Public Works Department as a surface dressing for the road, which is the main line of communication between the Northern and Southern Shan States.

Slags of former iron-smelting operations.

At mile 12 hard, greyish blue limestones with small brown inclusions of siliceous matter occur, a rock type which can be matched with certain varieties of the Silurian limestones further south.

The eastern boundary ridge of this valley undoubtedly consists of Lower Palæozoic rocks in which both Ordovician and Silurian horizons predominate. Judging from the limestones, the reddish brown sandy soils and the abundance of pine trees, the latter probably predominate where the valley is left between the 12th and 13th miles.

Silurian horizons probably occur about miles 12 and 13.

## WĀN PONG TO HSAIMONG (sheets 93 H/9 and H/13 ; 93 G/16 ; 93 K/4 and K 7).

From Wān Pong at an elevation of 3,300 feet and 69 miles from Taunggyi the road traverses sheet 93 H/13 in an easterly direction for 11 miles where it crosses the Nam Teng at about 3,200 feet above the sea. With the exception of a slight ascent and descent across a dry valley at mile 74-6, the whole of this length is a bare open plateau country which recalls the rolling downs of the country around Thamakan. To the north up the valley of the Nam Teng this expanse of plateau narrows but towards the south it broadens out and is studded with dozens of small sink-holes, while its monotony is broken by fantastic limestone hillocks which rise like steep islands above the surrounding country and form peaks such as Loi Tang 3,854, Loi Hpwe 3,672 and Loi Ti-ek 4,018 feet. To the south it narrows again to form a long plain, the central portion of the small State of Möngsit.

The limestone plateau between Wān Pong and the Nam Teng.

On the right bank of the Nam Teng and between the Inspection Bungalow and the suspension bridge by which the river is crossed at mile 86-5, exposures of brecciated Plateau Limestone are frequent but on the opposite bank beyond the bridge are earthy limestones and calcareous shales which are not unlike the purer varieties of the Permo-Carboniferous portions of the group.

Upper Plateau Limestones on the left bank of the Nam Teng.

After a short ascent from the Nam Teng valley, the road turns to the north-east and crosses the valleys of several small tributaries of the main stream. The country here is more broken and more thickly wooded; rock exposures are infrequent but such as are visible belong to the lower division of the Plateau Limestone.

At mile 87·7, however, a change takes place both in the geology and topography, for the limestones are unconformably overlaid hereabouts by red sandstones and associated rocks akin to the Namyau beds of the Northern States and like them probably of Jurassic age. Well banded red sandstones were found dipping to the north-east at 25°-30° at mile 90·2 and although later exposures are few and far between and consist mainly of weathered red and purple shales, seen particularly about miles 94·6 and 96·4 to 96·5, similar rocks doubtless persist for the greater part of this distance, though it is possible the limestone floor is not far away in places.

**A Red Bed series overlies the Plateau Limestones.**

The Red Beds, here as elsewhere, give rise to an intricate network of small steep-sided valleys and ridges, covered with thick forest through which the road twists and zigzags its way from one small stream bed to the next.

The next Plateau Limestone exposures, however, typical of the brecciated group, occur at mile 97·7. The road, in the meantime has turned more to the east and left sheet 93 H/13 near Haining, 94·4 miles from Taunggyi, elevation 3,000 feet, and after traversing the extreme south-eastern corner of 93 G/16, for a distance of about three miles, enters sheet 93 K/4 in its south-western corner and traverses it to the neighbourhood of Kyusawk, mile 118·3, elevation 3,100 feet; here the direction changes more to the N. N. E. as far as Hsaimong in sheet 93 K/7, 129·6 miles from Taunggyi and 2,050 feet above the sea. Throughout the whole of this distance the Plateau Limestone (lower division) continues. Near Haining and forming a dominant feature of the landscape north of the road for many miles is the independent limestone ridge which culminates in Loi Pāngtan, 4,131 feet. Parts of it consist of precipitous limestone crags, on which large trees struggle for a roothold, forming a curious contrast to other and adjoining areas which have smooth rounded slopes and support nothing but a scanty growth of grass. The valley of the Nam Mawng, a southerly flowing tributary of the Nam Teng is crossed near Wanhpwi, whence the road follows the ill-defined valley of the Nam Nā-hka, a tributary of the Nam Mawng. To the north and the south this is bounded by limestone ridges but where the valley ends in the neighbourhood of Kyusawk and the slow descent to Hsaimong starts, the drainage is quite indefinite

**The Plateau Limestones appear again and continue to Hsaimong.**

owing to the numerous sink-holes and valleys of enclosed drainage which exist in great numbers on slightly higher ground joining the two slopes mentioned above. Beyond Kyusawk, however, the drainage is definitely into the Hwe Leng, a short north-easterly tributary of the Nam Pāng. Hsaimong lies in the Möng Nawng State while the remainder of the road after the Nam Teng crossing is mainly in Lai Hka.

**Sandy sediments of slight extent and unknown age near mile 118-5.**

With the exception of poor exposures of sandy sediments in road cuttings near mile 118-5, which do not appear to belong to the Plateau Limestone, a differentiation which is further emphasised by a thick growth of pine trees on the hills to the south about mile 118, the few rocks visible in the whole of this traverse were brecciated limestones.

**Character of the limestone topography.**

They form barren waterless country, generally clad in sparse jungle and thick grass, opening out occasionally into park-like stretches dotted with larger trees. Rarely, a little dry cultivation of a *taung-ya* variety is practised but the only permanently tended ground is to be found near the perennial streams and of these there are but few.

## HSAIMONG TO KUNHING (sheet 93 K/7).

**A steep descent down the Hwe Leng to the Nam Pāng.**

Hsaimong, 129·6 miles from Taunggyi, lies near the head of the narrow valley of the Hwe Leng at an elevation of 2,050 feet above the sea. This small stream flows directly in a north-easterly direction to the Nam Pāng and the road for the greater part of the way, is carved out of the steep hillside bordering it on the east. At Wān Lai-kam (136·5 miles) it leaves the Hwe Leng. Crossing the latter it sweeps round to the south-east and east reaching the right bank of the Nam Pāng at Kunhing 143·6 miles, elevation 1,615 feet.

**Brecciated Plateau Limestone at Hsaimong.**

Abundant exposures of brecciated Plateau Limestone occur about Hsaimong and indeed form the steep slopes which here hem the valley in. The last exposures occur at mile 130-2, where a soft broken variety is quarried on a small scale by the Public Works Department for road surfacing, and at 130-3, where a harder kind was

seen. This too is lined and seamed in all directions with calcified brecciation-cracks.

**A fossiliferous series between the Plateau Limestone and Red Beds.**

Following a short stretch with no exposures, rotten brown shales crop out between miles 130-6 and 130-7 and at the latter point give place to better outcrops of yellowish-brown, very argillaceous shales from which a few specimens of minute phyllopods, which Dr. Cowper Reed believes belong to the genus *Estheria*, were collected. At mile 131-1 thin layers of sandy shales of yellow and brown colours alternate with more argillaceous bands, the whole exposure being bent into a monoclinal fold. About 131-3 there is an interruption caused by a recently formed travertine bank.

**The shaly sequence.**

Throughout the greater part of mile 131, the road crosses a steep hillside made up of these rocks but here weathered down into clay and covered with grasses, ferns and small moisture-seeking plants. The whole of this ravine-like valley is filled by thick forest and tangled undergrowth, forming an impressive contrast with the grassy plateau above and behind.

Poor exposures of rather thicker, more sandy and redder shales occur at 131-6, the prevailing dip being down stream. These are followed by harder, indurated, pale olive-green shales, breaking along black-stained fracture planes. Harder, black, fissile shales are also found here.

At mile 132 similar rocks split readily into large slabs showing small pieces of fragmentary fossil leaves and bits of broken woody fibre. Included with them are soft, brown, well laminated, sandy shales and shaly sandstones which dip E. S. E.

**Occurrence of bands of limestone conglomerate.**

Mile 132-1 shows more dark grey shales with fragmentary plant remains while mile 132-2 displays a band of limestone conglomerate containing small, well-rounded sandstone pebbles, passing into a tough, impure limestone and followed by the usual alternations of shales. Another identical conglomerate band then follows, succeeded in its turn by hard, dark shales at mile 132-3.

Brown shales continue round a big curve in the road past miles 132-4 and 132-5 but are generally concealed under vegetable growth which becomes thicker as lower elevations are reached.

Between miles 132-6 and 132-7 there is an important change, the shales predominant up to this point giving place to the overlying limestones. These are massive light grey rocks with bands of a somewhat darker colour. Structures resembling calcareous algae occur in them and specimens were taken for further study. The limestones prevail to a covered bridge at the foot of a steep descent, the only other rocks visible being a few exposures of sandy shales half a furlong before the bridge is reached. The stream-bed is full of flattened pebbles of dark indurated sandy shales and sandstones evidently the more resistant varieties of the rocks described above.

**Limestones overlie the shales.**

Similar limestones are found at miles 134-1 and 134 where they are of a uniform composition and pale greyish-white colour. After an interval come bleached shales and purple and 'pepper-and-salt' sandstones, all very weathered, cleaved and broken. The dip is here to the south-west at 35° but the observation is uncertain.

At mile 135-7 there are bands of coarse conglomerate containing rounded pebbles of limestone and of red and olive shales. The conglomerates are very silicified, the thin silica veinlets cutting matrix and enclosed pebbles alike. The bands outcrop above the road and form an independent hillock. They are compressed enough to have developed a pseudo-stratification and continue to mile 135-6.

**A coarse basal conglomerate is followed by a Red Bed formation.**

The strata above the conglomerates as far as Kunhing, wherever exposures are seen, belong rather to the Kalaw Red Bed types than to the underlying brown, olive and carbonaceous shales and they contain no calcareous horizons. At mile 136-4 the small paddy plain of Wān Lai-kam occurs. Between miles 137 and 137-3, the soil belongs to sandy 'Red Bed' type rather than to the *terra rossa* of the Plateau Limestone. Poor exposures of red sandy shales and olive sandy shales occur at mile 138-2, just over the watershed between the Nam-oi and Hwe Leng streams. Hereabouts the road is metalled with water-worn sandstone pebbles which originally came from the same beds.

**Outcrops of the Red Beds between Wān Lai-kam and Kunhing.**

Between miles 141-1 and 141-2 the Nam Leng is crossed and the small narrow strath formed by the stream follows. It contains some travertine and a raised river terrace in which pebbles of the sandstones are common. Soft, bleached, purple sandstones and pale shales with a quartz vein, two feet across, are seen at mile 142.

The last exposures are about half a mile from Kunhing (143-6 miles, elevation 1,615 feet), and consist of very friable, intensely twisted, bleached and blotched purple sandstones and sandy shales. the dip and strike of which are not determinable.

**Correlation of the Mesozoic rocks.**

These occurrences have been described in detail because they represent the first expanse of Mesozoic rocks of any considerable extent east of the Loi-an coalfield. Lithologically the purple beds are identical with the Namyaus of the Northern States and it may be recalled that there they usually commence with a basal conglomerate. In no locality in the Northern States, however, have beds been found in direct sequence between this basal conglomerate and the underlying Plateau Limestone floor.

Whether the limestones and shales which underlie what is taken as the basal conglomerate in the present series of sections, represent the Napeng (Rhætic rocks) of the Northern States or some intervening horizon in the Jurassic system lower than the Namyaus, which are identified with the Bathonian, or again, whether they represent some hitherto undiscovered Triassic subdivision, is unknown. It may be recalled that the Napeng beds occasionally contain limestone, but there is little in common between the thin-bedded argillaceous dark coloured limestones described from them and the massive beds of grey and white limestone described here.

A specialist's opinion on the few fossils which have been obtained is necessary before the question is settled and it is to be hoped that it will be obtained as soon as possible.

## KUNHING TO THE SALWEEN (sheets 93 K/7, K/11 and K/12).

A rapid traverse was made by Sondhi from Kunhing (mile 143-6, elevation 1,615 feet) on the Nam Pāng to Takaw (mile 172-6, elevation 800 feet) on the Salween to the east.

A narrow strip of recent alluvium with travertine, with a maximum width of three furlongs where the road crosses it, forms the eastern bank of the Nam Pāng, and the denuded remains of raised terraces forming a few low isolated hillocks, built of loose sandy mud with small water-worn pebbles, border the plain on the east. Beyond this the road follows a torrential stream for some distance where nothing but thick deposits of travertine is seen till the head of the flat valley is reached. Here, mile 145, mudstones and shales

of deep biscuit colour are present but decomposition has proceeded far enough to reduce the rock to small friable bits to a depth of over 15 feet, so that no evidence of structure and bedding is preserved. No fossils could be expected from such material but a lithological resemblance to the lower Mesozoic rocks occurring west of the Nam pāng is strong. It thus appears that the Nam pāng has carved its valley through a Mesozoic basin of deposition here.

These rocks continue to mile 146, where brecciated Plateau Limestone is exposed for the next four and a half miles with the usual accompaniments of scenery and topography peculiar to this formation.

**Red Bed sandstone between at 150-6 and 151-7.**

Between miles 150-6 and 151-7 the road lies on a bright, brick-red; sandy soil. Although there is only one small exposure of red sandstone and only a few blocks of the rock scattered along this section of the road, yet from the character of the soil consisting mainly of bright red sand, and from the marked change in the general contours of the country and the type of vegetation, it is not difficult to conclude that this length of the road is laid on the Red Beds. This comparatively small outcrop of the higher Mesozoics is yet another instance of how, in Mesozoic times, deposition was confined to isolated valleys and basins in the Plateau Limestone.

The lower dolomitised division of the Plateau Limestone is again exposed at mile 151-7 and continues practically to mile 165-7 with the exception of a small stretch between 157-5 and the village of Nammawngun, where shale and mudstones of doubtful age occur in a few isolated sections. From 151-7 to 157-5 the road passes over a very rugged and dissected country; nothing but precipitous, serrated hill-ranges and enormous sharp chimneys meets the eye in either direction. East of Nammawngun the same limestone builds the great, well developed range from whose crest a similar parallel range is seen about a mile and a half to the east, with a deep yawning valley between, the valley of the Salween.

**Chaung-Magyi series forms the western bank of the Salween.**

From the crest the road winds its way down the *ghat* to the Salween with a drop in altitude of almost 3,000 feet. Plateau Limestone is exposed for about half-way down the slope, to near mile 165-7, where it is seen for the last time. Thence onwards pale, bleached, sandy shales and hard arenaceous mudstones are exposed in several good sections. The rocks appear quite suitable for the

preservation of organic remains but no trace could be found in the limited time available. Lithologically the light shales resemble some of the Older Palæozoic shales but in view of the entire absence of limestone bands so characteristic of the Older Palæozoics and the phyllitic nature of the shale, it appears very probable that this deposit may be a representative of the Chaung-Magyi series in which types of a similar description are known to occur. Moreover, undoubted types of the Chaung-Magyi series are seen further down, along the bank of the river, where they comprise highly crushed, splintery, black shale with a large amount of vein quartz. The occurrence of Chaung-Magyis here is of particular interest as it is the first outcrop of these rocks ever met in the cross traverse from Thazi to Takaw, a distance of about 280 miles, with the possible exception of a doubtful occurrence in the foot-hills bordering the Irrawaddy plain of the west, and for that matter it is the first occurrence reported from the Southern Shan States, although small bits of black shale probably belonging to this series, were found during the Möng-Nai-Melun traverse, described later on.

**Naungkangyis faulted into the Chaung-Magyis.**

At the point where the road meets the ferry, a small patch of olive-green shales, dipping strongly to the north and containing a Naungkangyi fauna, is found faulted into the Chaung-Magyi slates exposed just to the north.

Across the river the road was followed for a few miles where only the different members of the Chaung-Magyis were met. Huge boulders of granite are commonly seen in the stream beds and on the hill slopes and they do not appear to have travelled far, but no actual exposure of the rock was met.

## WAN PONG TO MONGNAI (sheets 93 H/9, H/13 and H/14).

Möng Nai, the capital of the State of the same name—the largest and most important of the group of States in the south-eastern division– , lies on one-inch sheet 93 H/14, 47 miles to the south-east of Loilem with which it is connected by a good motor road. This leaves the main Taunggyi-Kēngtung road at mile 71-5, 2½ miles to the east of Wan Pong. From this point it trends to the south-east as far as Hai-pak (mile 87-3), across part of sheets 93 H/9 and 13 of the one-inch survey.

Throughout the whole of this distance the country traversed forms part of the same limestone plateau already described as

existing further north between Wān Pong and Hsaimong, on the main easterly route. Its characters to the south are identical; it is an undulating grassy plateau, waterless except for two larger streams and an occasional spring, its monotony broken by a few stretches of open savannah in which bracken flourishes beneath the trees or by bamboo groves and great banyan trees denoting the sites of scattered villages or, again, in this particular region, by islands of rocky limestone peaks which rise abruptly from the surrounding country and add a pleasing diversity to the landscape. Across this country the road gently rises and falls crossing from one dry valley to another until at 82-3 it reaches the head of the Nam Tawng valley which later flows to the south through the Mong Pawn plain (sheet 93 H/14).

**Southern extension of the Plateau Limestone.**

Rock exposures are as a rule exceedingly scarce but the all-pervading bright red soil—the typical *terra rossa* of the Northern States indicates, if the character of the country itself did not do so sufficiently well, the presence of the Plateau Limestone underneath.

**Outcrops of the brecciated limestone.**

The first exposures of the brecciated limestone of the Plateau group beyond Wān Pong occur at mile 69-7 and again at 70-2. A spring at 72-3 and a goodly stream at mile 74, are rare enough occurrences to demand special mention. This stream, formed from many smaller ones draining the hilly Silurian country to the west and south of Wān Pong, disappears into the ground within two miles of the main river of the region—the Nam Teng. Isolated exposures of grey brecciated Plateau Limestone crop out beyond it between miles 74-3 and 74-4. Between miles 75 and 76 the limestone hill of Loi Tang (3,854) forms a prominent land mark on the east, while to the south is a group of several more which attain heights of over 4,000 feet above sea level.

At mile 77-7 the road passes close to the crags of an outlying member of this group and there are abundant outcrops of a dark, greyish blue, unbrecciated limestone which is fossiliferous and bears brachiopods, corals and foraminifera. A single specimen of a small elongated gastropod was obtained. These rocks belong to the Permo-Carboniferous section of the Plateau group but the old brecciated floor on which they rest protrudes through the surface in the vicinity. The soil too hereabouts loses its distinctive red tint.

**Fossiliferous limestone.**

At mile 78-4 there are abundant exposures of brecciated limestone again but at mile 80, a hillock rising to 3,786 on the south-east may belong to the younger portion of the group. At mile 81 limestone hills rise on both sides of the road but the older rocks are exposed again and again at 81-4. Descending from mile 82-3, there are poor examples at 84-3, while from 85-6 (beyond Mai-niu village) to 85-7, the exposures of the brecciated variety are good. A small limestone island lies to the east at mile 87, before reaching Hai-pak at mile 87-3.

**Alternations of both varieties of limestone.**

To the south of Hai-pak the road skirts the foot of a hill range to the west and the plateau-like type of country gives place to steeper slopes clothed in thick forest. At mile 88-6 there is a small isolated limestone hill to the east. About this point the descent to the Nam Tawng commences and there are no exposures, though the red clayey soil continues to mile 90-6. Here pale brown mudstones similar to those found near Hsaimong and presumably older than the Mesozoic Red Beds occur, but they are of small extent and may represent merely a small patch of these beds lying on the surface of the Plateau Limestone.

**Mesozoic rocks to the south of Hai-pak.**

The Nam Tawng, here flowing north and south, is crossed at mile 90-7, but the only exposures in its bed are of soft recently formed travertine. Sandstone pebbles are, however, common in the stream. Continuing close to the stream and above it on its eastern bank, for the next two miles, a stretch of thickly wooded country is traversed closely overshadowed on the east by a well developed limestone ridge, rising to 3,730 feet and separated from Loi Hkang (4,096 feet) further east by two dry valleys of enclosed drainage. Near mile 92, off-shoots from the craggy ridge reach the road and consist of grey brecciated limestone of the Plateau type.

**A limestone ridge borders the Nam Tawng valley on the east.**

Further south still low spurs from these eastern hills, containing no surface rocks, are followed, while to the west the Nam Tawng flows in a narrow paddy plain at the foot of the steep range which borders it on this side, and rises steeply to 5,184 feet in Loi Sāng, to 4,150 feet in Loi Patwo, and to heights of over 5,000 feet, culminating in Loi Lom, 5,939 feet, a short distance further south.

The actual plain is not reached till mile 95 and at mile 98-1, where the Nam Tawng is re-crossed, it is left for the end of a spur

from the west which separates the parent Nam Tawng from its easterly flowing tributary the Nam Sa-lai, both perennial and fair-sized rivers for this part of the world.

**Differences of the eastern and western walls of the Nam Tawng valley in Möng Nai.**

It is necessary here to invite attention to the differences between the eastern and western ranges which form the boundary walls of the Möng Nai plain. That on the east appears to be limestone as far as the eye can reach. Irregular jagged crests, steep and in some places precipitous slopes, disappearing streams and cauldron valleys stamp the former with their own unmistakable character. The other, from the first crossing of the river at mile 90-7, to where it is broken by the Nam Sa-lai, is more regular, with its stream valleys flowing straight down to the east without a break. It is moulded into generous smoothy-rounded outlines and is thickly forest-clad from base to crest. These topographical peculiarities bespeak a change of lithology and of geological formation. Time did not permit a proper examination but a clue to the problem lies in the rocks found in the bottom of the Nam Tawng at the second crossing (mile 98), where there are good exposures of massive light grey shales with rare fragments of broken vegetable remains. These may belong to one of the Mesozoic groups and perhaps underlie the mile of higher ground across the spur before the plain of the Nam Sa-lai is reached. The debris in the latter river consists almost entirely of hard sandstones of many varieties, most of which can be matched petrologically with known specimens of Jurassic age.

The hills on the south of the Nam Sa-lai bordering the plain between it and Möng Nai are formed of Plateau Limestone and it would appear as though here the limestones of the eastern wall had crossed to form the western, replacing the other rocks, whatever they may be, which occur to the north of the Nam Sa-lai valley.

**The Möng Nai plain.**

The Mong Nai plain, which is about 16 miles long, attains its greatest width of four miles about the latitude of the capital. Although at its northern end, the streams possess moderate gradients and fairly rapid flow, towards the centre and south these fall away and there is some stagnant water and marshy ground. The plain has the appearance of an old lake-bed but no trace of terraces was discovered. Near mile 98-1, however, there is a great development of tufa, one band being 12 to 15 feet thick with the base not exposed. Leaves of recent

species of trees are common in this in an almost perfectly preserved condition.

**MÖNG NAI TO MELUN (MÉ-LAWN) (sheets 93H/14 and H/15).**

Many of the picturesque pagodas in Möng Nai itself and on the hills to the south-west of the town are perched on pinnacles of older Plateau Limestone and a short traverse by Sondhi to the west of the capital revealed nothing but the same rock in that direction.

**Older Plateau Limestone around Möng Nai.**

On the main road to Mawkmai, however, the capital of the State of the same name adjoining Möng Nai on the south, on which Melun lies at 15 miles from Möng Nai (mile 104) and in the valley of a small tributary of the Nam Tawng, rising to the south-west, outcrops of rotten red sandstones and shales are found which persist to between mile 105·5 and 105·6. These undoubtedly overlie the limestones which on the north of the road are exposed in small cliffs and rocky masses. The red rocks resemble in every respect typical varieties of the Red Beds of Kalaw.

**Thin remnants of Red Beds overlie it to the south.**

As the road ascends they are soon replaced by brecciated Plateau Limestone of a normal type. Between miles 107·7 and 108, however, brown shales, sandy shales, fine-grained felspathic sandstones and fine grits, full of rounded grains of stained quartz, are found. These beds, which recall the Lower Jurassic of other places, are exceedingly crumpled and broken. It is believed that they fill a hollow in the limestone floor and that their twisted condition is largely a result of subsidence through solution of the underlying strata.

**Lower Jurassic ? preserved by subsidence.**

More limestone follows, appearing in the road sections as rounded pinnacles buried under the universal red clay. Between mile 108·3 and 108·4 there lies a patch of light coloured shales so traversed in every possible direction by cracks that they fall into fragments from a light blow. Associated with them are more brown sandstones and a band of excessively crushed olive shale.

From this point to Melun no more Mesozoic rocks occur and every outcrop seen belongs to the lower division of the Plateau Limestone. Always brecciated, generally grey or light greyish blue in colour, some of the local varieties are as white as chalk and in these the rock is at times so shattered that the road side cuttings

**The older Plateau Limestone recurs.**

literally fall to powder on exposure and slip on the highway in shoots of calcareous 'sand'. As a contrast, great cliffs can be seen on practically every hillside around, rising in places vertically for hundreds of feet, yet composed of another variety of the same rock.

The road keeps to its general south-easterly direction and at mile 113 or thereabouts crosses the watershed between the Nam Tawng and the Nam Nyim. About this point, too, lies the boundary between the States of Mōng Nai and Mawkmai. High ridges attaining heights of 5,800 feet above sea-level close the view to the east; to the west the country is more broken and the peaks there—probably all of Plateau Limestone—rarely reach heights of 4,000 feet.

The limestone bands which build up the mass of Loi Tang close to the road at mile 113 are better developed than usual. About mile 114 local *Taungthus* attempt the only cultivation seen along the road and it is of a temporary, 'dry' character. Near mile 116 occur the first outcrops after a long stretch of deep, soil-covered savannah. A steep descent at 116·2 reveals further exposures of deeply brecciated, soft rock into which the roadway has been carved, while there are good examples of the finely powdered rock at mile 118.

**Acidic igneous rocks not in situ near Melun.**

At mile 118·7 is a dry stream bed which is perhaps the most interesting feature of this section, for in its dry bed are pebbles and boulders of granite, pegmatite and greisen, of dark silicified fine-grained igneous rocks, of slates, quartzites and fine-grained phyllites of the Chaung-Magyi series, and of vein quartz which appears to have been strongly mineralised and which in places still carries fragments of iron pyrites.

A thick gravel deposit of more ancient date lies above the level of the present bed, but the only mineral obtained from it by panning tests was magnetite in microscopic octahedra.

Looking to the east up the valley of this stream it appears to issue from a limestone canyon one or two miles away. Its watershed however, lies on the high north-and-south running ridge already mentioned as rising to altitudes of over 5,800 feet, and it is probably from this that the granites, etc., and the older rocks are derived. Two varieties of granite are present, one a medium grained muscovite-bearing species and the other a somewhat coarser

kind with biotite and large phenocrysts of orthoclase felspar. In addition to these there are various dark-coloured rocks which may be silicified rhyolites and rhyolite tuffs. The sedimentary rocks consist of hard, indurated, dark grey and light green slates for the most part.

## THE OLD SILVER MINES OF MAWKMAI (sheet 93 H/15).

Mr. Sondhi made a traverse from Melun to the 'Old Silver Mines' marked on the one-inch map (sheet 93 H/15) about ten miles S. S. W. of Mongnai as the crow flies.

**Upper Plateau Limestones between Melun and the old mines.**

Between Melun and the old mines the rocks consist of platy tabular limestones and interbedded shales, the former bearing remains of fossils and belonging to the upper division of the Plateau Limestone. The shales seem to occur entirely to the south-west of Sai-hok for beyond this village no exposures of them were seen in the limestones. The strike is north and south with high dips. To the east of the deserted mines there is a well-marked north and south ridge containing peaks of over 5,800 feet and this appears to be made of the older rocks of the Chaung-Magyi series into which the granites may be intrusive.

**Description of the old lead pits.**

The old lead pits are in the younger limestone. The excavations are not extensive and appear to be confined to loose material in fissures along the strike. These are full of soil or clay in which small nodules of galena occur. On their sides, however, recrystallised limestone splashed with flecks of galena, altering externally to cerussite, are found. No quartz was seen in the places examined. Copper staining is occasionally present and the recrystallised limestone is converted in patches into a greenish calcite. This rock also contains a little pyrite. Small masses of limonitic gossan exist in the fissures in addition.

The limestones continue at least half a mile to the east, as the crow flies, before they are replaced by the older rocks.

On the high ridge across the valley to the north and along the same strike, similar excavations together with a shaft 15 feet wide and 30 feet deep, are reported to occur. According to local tradition the pits were opened 60 or 70 years ago by Shans and Chinese but there are no records of any local metallurgical operations and no slags have been found.

A *Taungthu* inhabitant of Melun produced for our inspection a small button of hard, rough cast lead and the suspicion is perhaps pardonable that until recent times at any rate, local *shikaries* may have been accustomed to extract a little galena and make the lead bullets which are still the local ammunition.

It was impossible to come to any decision as to the potential value of the 'mines' in the short time at our disposal, but the proved occurrence of galena and the interesting examples of igneous rocks from the vicinity, indicate that the whole neighbourhood is one which deserves methodical, large-scale mapping and careful prospecting.

## MELUN TO MAWKMAI (sheets 93 H/15, H/11 and H/12).

Mr. Sondhi traversed the 12 miles which lie between Melun and Mawkmai further south. From the former place at 119 miles, the road gradually descends to mile 123 in a general south-south-easterly direction across brecciated Plateau Limestone the whole way.

**Another patch of Mesozoic rocks.**

Following a significant change in the colour of the soil from the red *terra rossa* to a yellowish clayey material, shales are found at 123-4. These are of an olive colour, shattered and powdery and probably belong to one of the Mesozoic groups. They continue to mile 125-7 in disconnected outcrops. At 124-6 and 124-7 they contain calcareous horizons.

**The high level terraces of the Ho-pom-Mawkmai plain.**

Disconnected remains of sub-recent terraces are found at intervals from mile 124-4 to 125-7. Here the Ho-pom paddy plain is encountered, and the only rocks visible consist of travertine. About a mile south of Ho-pom, there is a sudden drop of approximately 300 feet to the lower level plain of Ponglau-Mawkmai. The conclusion cannot be resisted that there is a resemblance between these conditions and those obtaining in the case of the Yawnghwe plain which is itself overshadowed by a high, level flat of sub-recent origin, in other words, the physiographical changes which affected the Inle valley have also influenced the Mawkmai plain to much the same extent. Evidence is not wanting that these changes were widespread over the whole of the States.

## MÖNG NAI-LANGHKO ROAD (sheets 93 H/14 and H/15).

This road was followed for 13 miles to the S. S. E. where it leaves one inch to one mile sheet 93 H/15. Looking in this direction from Mong Nai, the rugged limestone hills which close the valley in on the east and west give place to a much flatter topography, though on the far side of the Nam Teng valley, towards which the Nam Tawn (Nam Tawng) after flowing through the Möng Nai plain makes its way, there is a ridge which attains a considerable altitude above sea-level.

**Older Plateau Limestone to the south of Möng Nai.**

Keeping to the higher ground at the western edge of the plain, no rock exposures are visible under the thick soil cap until the 3rd milestone is passed when brecciated limestones of the Plateau group crop out. Exposures are again completely concealed in the next mile.

**It is followed by an extensive basin of Jurassic rocks.**

At To-nang, five miles, the Nam Tawn is crossed and just beyond it pieces of purple sandstone and brown mudstone occur in the thick surface soil. The road now continues wandering steeply up and down through sparsely forest clad, deeply dissected country. Ascending past Kyawktawng there are more brown shaley mudstones with lighter bands in places, the whole series being extremely broken. At 8·5 miles more smashed up sandy shales occur and beyond this point to 12 miles there follows an excellent sequence of Jurassic rocks.

At 8·5 miles sandstones are replaced by finely laminated argillaceous limestones, followed in their turn by shales and sandstones. Beyond Pāngpau-long at mile 9·5, limestones are found overlain by light-coloured, speckled sandstones, dipping S. S. E. at 30°-35°, with interbanded, bleached purple, sandy shales. Similar rocks continue through the 10th mile. In the 11th mile the limestones are more frequent. There are few exposures in the 12th mile owing to the flatter country and thicker soil, but following a steep rise there comes a repetition of the impure limestones and sandy shales again. Just here there is much local contortion and in places the shales are crumpled and phyllitic. The general dip is to the south-east at 20°.

Some of the browner rocks seen in the early part of this traverse may be of Rhætic age but the great mass of the exposures probably belong to the Namyaus. They weather into an unusually sterile, red, sandy soil and under general subaerial denudation form low

but excessively sculptured country full of small steep ravines running in all directions.

The area occupied by them is practically uninhabited, the forest open and the trees, except along the dry water-courses, stunted.

## EXPLANATION OF PLATES.

PLATE 3, FIG. 1. Close view showing the characteristic pattern of the phacoidal limestones interbedded with mudstones at Loilem.

FIG. 2. Panoramic view of the Silurian deposits at Loilem, with limestones full of sink-holes in the background.

PLATE 4.—Calcareous growths in the Htamsāng caves.

PLATE 5.—Geological sketch map of the country traversed by the main road between Taunggyi and the Salween river, Southern Shan States. Scale, 1 inch = 16 miles.

# THE GEOLOGY OF THE COUNTRY BETWEEN KALAW AND TAUNGGYI, SOUTHERN SHAN STATES.

BY J. COGGIN BROWN, O.B.E., D.Sc., *Superintendent, and* V. P. SONDHI, M.Sc., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 6-11.)

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## CONTENTS.

## INTRODUCTION.

The region described in this paper occupies an area of approximately 1,370 square miles lying between latitudes 20° 30′ and 21° 0′ and longitudes 96° 27′ 30″ and 97° 12′ 30″. It is comprised within Survey of India, one-inch sheets Nos. 93 D/9-13, D/10-14 and 93 H/1. It includes very small portions of the Meiktila and the Yamethin districts of Upper Burma, while the rest is occupied by numerous small Shan States, together comprising the Myelat, and parts of the large states of Yawnghwe and Lawksawk, which lie to the east and north of them respectively. The small Shan States comprise the whole or part of the following:—Poila (Pwela),[1] Tatpot, Myinmu, Kyong, Hsamönghkam (Thamakan), and Mawnang (Bawnin), which are under the administrative charge of Poila, and Mawsön (under the jurisdiction of Yawnghwe), and Pangtara (Pindaya), Hopōng and Pangmi.

The area consists of an elevated tableland for the most part approximating 4,000 feet above the sea-level and lying beyond the outer hill-ranges which divide it from the plains of Upper Burma further west; but it is itself traversed by parallel north and south ridges rising to over 5,000 feet and by inter-mountain valleys which, in the case of Yawnghwe valley, descend to 2,900 feet above the level of the sea.

Enjoying a comparatively cool climate, in it is situated the hill station of Kalaw, while at Taunggyi, 44 miles further east, are the head-quarters of the Commissioner and the Council House of the Chiefs of the Federated Shan States.

It is traversed by the Southern Shan States branch of the Burma Railways which terminates at Shwenyaung in the Yawnghwe plain, 98 miles from the junction with the main line at Thazi and 404 miles from Rangoon; and it is crossed by the great eastern road

[1] The Burmese names by which the states are often known are given in brackets.

which links Burma with the outlying trans-Salween state of Kēng tūng, and with the Chinese province of Yünnan and the kingdom of Siam beyond.

Within this region rocks of Ordovician, Silurian, Devonian, Permo-Carboniferous, Jurassic, Cretaceous, and Plio-Pleistocene age occur; it forms indeed a key area to the study of the geology of the whole of Southern Shan States, while its known mineral deposits include ores of copper, silver and gold, lead, tungsten and antimony, together with coal and lignite.

## PREVIOUS OBSERVERS.

F. Fedden, 1864-65.

During the field season of 1864-65 F. Fedden of the Geological Survey of India travelled through the Shan States from south to north. Entering the hills near Yamethin, 110 miles south of Mandalay, he crossed the Myelat on his way to Kehsi Mansam and the Salween; but beyond his notes on lead smelting and silver cupellation, at that time in active progress there, little assistance is to be gained from his results, which merely record the rocks seen each day along the route with no attempt at their co-ordination.[1]

E. J. Jones, 1887.

In 1887, E. J. Jones of the Geological Survey of India, visited various localities to investigate coal, lignite and other mineral deposits. As the country was then only just recovering from wide-spread banditry and as the only map available was on the scale of 16 miles to 1 inch, Jones could make no attempt to survey geological boundaries and confined his attention strictly to the mineral occurrences.[2]

C. S. Middlemiss, 1899-1900.

The topographical survey of the sheets with which we are concerned was made during seasons 1893-94 and 1898-99, and in season 1899-1900 C. S. Middlemiss made a geological reconnaissance in parts of the Southern Shan States and Karenni. This work is of fundamental importance in Shan geology and we have therefore to devote some attention to it here. Middlemiss stated[3] that his notes do not pretend to be anything more than rough geological jottings.

[1] F. Fedden, 'Journal of the Salween Surveying Expedition', *Sel. Rec. Govt. Ind.*, XLIX, p. 30, (1865).

[2] E. J. Jones, 'Notes on Upper Burma', *Rec. Geol. Surv. Ind.*, XX, pp. 191-194, (1887).

[3] 'Report on a Geological Reconnaissance in parts of the Southern Shan States and Karenni', *Gen. Rep. Geol. Surv. Ind.* for 1899-1900, pp. 122-153, (1900).

His object was to cover as much ground as possible in the available time and to ascertain the possibilities of the country, rather than to make even a sketch-survey. He split up the geological fabric of the hills into a number of zones of distinctive character as regards composition and stratigraphy, as follows[1] :—

(1) Gneissic and metamorphic zone.

(2) Great Limestone zone.

(3) Purple Sandstone zone.

(4) Sub-recent conglomerates, sands, and loams.

The gneissic and metamorphic zone, the western edge of which rises steeply from the plains of Meiktila and Yamethin, is outside our area, but is well exposed in sections along the motor road from Thazi to Kalaw between Hlaingdet (mile 9) and Pyinyaung (mile 31). Middlemiss's descriptions[2] of these important sections are given here for the sake of completeness, with our comments upon them in brackets following. The first rocks met with are well foliated micaceous and hornblendic gneisses, intruded by veins of pink syenite, white pegmatitic granite, and fine grey micrograpite with biotite and muscovite.

**Road observations between Thazi and Kalaw.**

As the road begins to wind among the hills towards Yinmabin, sub-metamorphic quartzites and slates set in, splintered and split into platy layers. Near Yinmabin a fine-grained gneiss occurs, together with pale-coloured quartz-felsites or microgranites. East of Yinmabin the white quartzites and slaty rocks are less metamorphosed and plainly indicate their sedimentary origin. Interbedded with them are occasional very thin bands of dark blue-grey limestone a foot or two wide. All are very much smashed. Further north-east towards Pyinyaung greenish grey, dark quartzites and black, slaty, sub-schistose rocks continue—all much fractured—and there are repetitions of all the rocks from Yinmabin over again. Near Yebokson there is a green and white mottled gneiss.

We have given these details of the road section here because they are the only ones available, because they are published in a little known report which is now out of print, and because we are frequently requested by travellers for information about the rocks along the well-known road.

[1] *Loc. cit.*, p. 127.
[2] *Loc. cit.*, pp. 128, 129.

A little to the east of Pyinyaung the road enters the first of Middlemiss's Great Limestone zones. Here, he wrote:—[1]

'we find a set of towering crags forming a long ridge densely covered with forest and lifted high above the surrounding country. This band of limestone is isolated from other bands to the eastward by other rocks afterwards to be described'. (His 'Purple Sandstone Zone' which we now recognise as a great basin of younger Mesozoic rocks of Jurassic and Cretaceous age). 'The band runs a perfectly straight course north and south. Through it in a narrow, gloomy defile dashes the Pyinyaung river by a cross rift, exposing the rock on both sides. The rock is dark and light blue-grey, massive, compact, and but slightly brecciated with recementation by calcite veins. One can see no definite bedding in it and no regular variety in its composition. ............The ridge possesses very steep rugged slopes littered with titanic blocks, all emphasizing its very massive character. ............The gorge is about one mile long through the limestone.......... The same band can be seen stretching away north and south for many miles.' (It is familiar to passengers by the hill railway between Lebyin and Sintaung).

The Purple Sandstones zone is very well seen in excellent exposures along the main road between a point four miles east of Pyinyaung and Kalaw. Shortly after leaving the limestone gorge just mentioned[2]

'and crossing a short thickness of slightly metamorphic pale greenish grey slates and white quartzites with vertical or very high dip' (representatives of the Loi-an series or Coal Measures of Jurassic age as we know them today)' the road turns south-south-east, and follows a long open valley in these purple rocks as far as Nampandet, and then ascends by zigzags to Wetpyu-ye (mile 53) and Kalaw through the same rocks. These purple rocks appear in the section in a sudden manner as if by faulting.

They consist of a very characteristically coloured set of rather soft sandstones and shales, and hardened clays, with occasional conglomerates. Their general colour may best be described as a dark brick-red or chocolate-purple; ..........

As compared with the Pyinyaung limestone and the associated metamorphic and highly fissile rocks, this purple sandstone group is but moderately disturbed, the dip throughout its complete length being 30° and less, first in towards the metamorphics and then spreading out across the low valley, which, save for the forest is fairly open and shallow.'

The purple rocks we now know to be of Cretaceous age, as suggested first for similar strata in the Northern Shan States by C. L. Griesbach in 1901, and they lie at gentle angles of from 25° to 30° on the steeply upturned edges of the Jurassic Coal Measures below them, in these particular exposures.

[1] *Loc. cit.*, p. 133.
[2] C. S. Middlemiss, *loc. cit.*, pp. 143, 144.

'The slopes facing west are often gentle dip slopes; those facing east steeper scarps. In some places along this piece of road section, as near Nampandet and Kalaw, the interbedded conglomerates are of considerable coarseness and thickness. They are seen to be an angular or sub-angular conglomerate, the fragments being often very large and composed of harder bits of a similar purple sandstone to those interstratified with them; but a few smaller and more rounded pebbles are of grey limestone. Sometimes along this stretch of country the cuttings expose sandstone of brown-grey or pepper-and-salt colour' (more representatives of the Coal Measures).

'The width of this zone here is about five miles. It has an obscure contact with the Thamakan limestone east of Kalaw.'

The Thamakan limestone is the older brecciated dolomite of the Plateau Limestone group into which the Mesozoic rocks are faulted.

Middlemiss's last zone contains the Plio-Pleistocene to Recent deposits of the inter-mountain plains of Thamakan, Heho and Yawnghwe.

'The rocks are sometimes coarse, loosely coherent conglomerates, or hardly solidified pebble beds, with a matrix of sand, the pebbles being very generally hard quartzite, but sometimes limestones. Associated with them are light-coloured sands and pale bluish grey clays and loams, sometimes splashed with red. In a few places a bed or beds of lignite............are found. The whole is either quite horizontal or with only insignificant dips of a few degrees. They spread out and then fall away locally along the stretches of level plateau, so that it is often quite arbitrary where their boundaries are placed.'[1]

On the map accompanying Middlemiss's report, but not published with his paper, he distinguished between the 'Grey Limestone (Thamakan Limestone)' and the 'Limestones with obscure Fossils.' He also wrote as follows[2]:—

'At one time during the progress of my work I had hoped to further divide the great limestone zone into sub-zones of separate geological age and of slightly different composition. Further work ............has, however, shown me that even if any differences might be made on palæontological or petrological grounds (as to which no positive evidence is yet forthcoming) the rocks could not certainly be traced north and south in recognizable bands in the same definite order that I consider necessary if they are to be judged of any value as structure zones that imply anything vital regarding the evolution of the mountain mass.'

To-day we know that the limestones belong to the Ordovician, Silurian, Devonian, and Permo-Carboniferous systems, but it is only by laborious detailed work and the help of palæontological specialists in Europe, for most of the assemblages and many of

[1] *Loc. cit.*, p. 147.
[2] *Loc. cit.*, p. 130.

the forms appear to be new to science, that we have arrived at our classification. There is no wonder that Middlemiss, labouring under the difficulties of this country, hampered by obstacles of which daily rapid marching was not the least, should have missed the older Palæozoic rocks, indeed, it is remarkable that in his 'rough geological jottings', he left such an indispensable store of knowledge for workers like ourselves who have found it of the greatest assistance.

At the time Middlemiss was working here, T. H. D. La Touche was commencing his investigations into Northern Shan geology which culminated in the publication of his memoir and maps[1] of the greater portion of the Northern Shan States. This memoir and the series of great monographs by F. R. Cowper Reed, C. Diener, S. S. Buckman and Miss M. Healey published in the *Palaeontologia Indica* in which the fossils collected by La Touche and his co-workers are described, form the foundation of the systematic geology of the Shan States.

T. H. D. La Touche 1900-1906.

Early in 1922, G. de P. Cotter spent a month on the Loi-an coalfield and produced a detailed report on that field and other associated coal occurrences, which unfortunately is treated as a confidential document. He proved that the Coal Measures contain a flora of Middle Jurassic age and regarded the purple and red sandstones and conglomerates of the Kalaw neighbourhood as Upper Jurassic or Cretaceous. We have made liberal use of some of Dr. Cotter's purely geological observations.[2]

G. de P. Cotter, 1922.

The late Captain F. W. Walker worked with Dr. Cotter and on the latter's departure from the area, continued the systematic survey of sheets 93 D/10 and 14, but was removed to Burma before completing these. We have utilised Walker's boundaries (in places revised by Sondhi) of the Mesozoic rocks with the Plateau Limestone in the preparation of the map which accompanies this report. He, like other geologists before and after his time, failed to realise that the rocks of the range separating the Heho and Yawnghwe valleys do not belong to the Plateau Limestones.

F. W. Walker, 1922.

[1] T. H. D. La Touche, 'The Geology of the Northern Shan States', *Mem. Geol. Surv. Ind.*, XXXIX, Pt. 2, (1913).

[2] G. de P. Cotter, 'Report on the Coal-Field of Loi-an', Govt. of Burma Press 1922) (Confidential).

In June, 1925, E. L. G. Clegg paid a short visit to Mawsön. He described the area as consisting of rocks of the Plateau Limestone formation.[1]

E. L. G. Clegg, 1925.

C. S. Fox spent a few days at Kalaw in January, 1929, and was fortunate to discover ammonites in the Red Beds there which, according to Dr. Cotter, are of Cretaceous age, thus proving the opinions originally advanced by Griesbach and by Cotter himself. Dr. Fox has also tentatively suggested the correlation of certain beds which occur near mile 38 of the Thazi-Kalaw road with the Bunter division of the Trias, a suggestion with which we are unable to agree.[2]

C. S. Fox, 1929.

In another publication Dr. Fox has advanced a theory regarding the Plio-Pleistocene deposits of the Shan States and their enclosed lignite deposits, which we regard as inadequately founded. It is referred to later under the section dealing with lake deposits.

Our own work in this region commenced in field-season 1928-29, devoted at first to a study of the lead-ore deposits of Mawsön. The senior author has continued his investigations as freedom from other duties permitted until the present time. In season 1930-31 he was joined by V. P. Sondhi who is responsible for the whole of sheet 93 H/1 and has completed parts of sheets 93 D/9, D/10, D/13 and D/14, including the difficult terrain west of the longitude of Kalaw.

On the map accompanying this report, only a broad general classification of the larger rock groups has been given. More detailed subdivision is at present likely to remain impossible owing to the natural obstacles, which everywhere confront the geological surveyor in the Shan States. In this connection we invite attention to the remarks of three distinguished geologists who all possessed considerable experience of this field.

Difficulties of survey work in the Shan States.

C. L. Griesbach, Director of the Geological Survey of India, wrote as follows :—

'In a country such as the northern Shan hills, which is not only covered with extensive forests and dense under-growth, but the surface of the rocks of which is so greatly disintegrated that frequently the actual rock is covered by a soil-cap of some fifty feet in thickness and more, it is extremely difficult to arrive at anything but a mere outline of the geological structure of the area beneath the soil.

[1] General Report for 1925, *Rec. Geol. Surv. Ind.*, LIX, p. 46, (1926).

[2] C. S. Fox, 'The Occurrence of Cretaceous Cepalopods in the Red Beds of Kalaw', *op. cit.*, LXIII, pp. 182-187, (1930).

cap, and therefore the details of the geological sections can never be more than mere guesses, but fortunately most of the beds contain fossils and therefore their ages may be ascertained approximately.

It is not possible to do more than establish a number of series of beds, which so far have eluded close comparisons, owing to the fact that they mostly occur in localities separated from each other by tracts within which none or only very bad exposures have been observed.'[1]

T. H. D. La Touche, after seven years field-work, stated that, except in the beds of the streams, and along the cuttings of the new roads, outcrops of the rocks are not often met with, owing to the thickness of the cover of clay and soil in which the hill-slopes are buried. For this reason anything like a continuous section is not to be seen, so that it has been found impossible to trace the different varieties of rocks from one locality to another.[2] In this particular case La Touche was referring to the Pre-Cambrian Chaung-Magyi rocks. Regarding the Lower Naungkangyi stage (Ordovician) he wrote :—

'The great variation in the lithological character of the rocks at the different localities from which fossils have been collected, and the fact that in many cases particular forms have only been found in one locality, renders it extremely difficult to trace any connection between the occurrences at one place or another. ........ It will be necessary therefore to describe each outcrop where collections of fossils have been made, separately, and only to attempt to correlate them with each other when such a course seems to be justified by a similarity in the fauna.'[3]

In another place La Touche was compelled to emphasise again these difficulties, adding,

'Even where a rich fauna occurs it is often impossible to be quite sure to what horizon it belongs, owing to the extraordinarily isolated and unique character of the exposures.'[4]

Dr. Cowper Reed refers to the subject as follows :—

'Apart from the Sedaw beds, the Lower Naungkangyi division has rather a poor fauna; and in the present state of our knowledge it seems of little use to attempt to recognise smaller sub-divisions in the series, for the occurrence of fossils at isolated points and the local differences in the organic assemblages, though the rocks may be lithologically similar, render the recognition or tracing of the same horizon a matter of the utmost difficulty or of pure speculation.'[5]

It is true that in our area, the only densely forested tract lies in the west, over the edge of the plateau proper, but in addition

[1] C. L. Griesbach, *Gen. Rept. Geol. Surv. Ind.*, 1900-01, p. 17.
[2] T. H. D. La Touche, *loc. cit.*, p. 48.
[3] *Ibid.*, p. 69.
[4] *Ibid.*, p. 112.
[5] F. R. Cowper Reed, 'New Ordovician and Silurian Fossils from the Northern Shan States', *Pal. Ind.*, N. S., Vol. VI, Mem. No. 1, p. 96, (1915).

to the universal soil and clay cap we have had to contend with added hindrances in the lithological similarity of the various divisions of the Lower Palæozoic limestones, with the absence of easily identifiable groups like the Nàmhsim sandstones of the Northern States and in the occurrence of new horizons with undescribed faunas, previously unrecognised elsewhere in these regions.

It is hoped that this explanation will to some extent account for the diagrammatic character of our map, justify the unusual and somewhat disconnected method of description adopted in this report and will be taken into consideration should later work entail the modification of any of our conclusions.

## PHYSICAL GEOLOGY.

When the traveller to Kalaw by the road reaches the crest of the final ascent just outside the town, he crosses the watershed of two great river systems, the Irrawaddy and the Salween. By the railway route it is traversed, together with the boundary line between Burma and the Shan States, at Myindaik, the first railway station below Kalaw As though to mark this important feature the semi-tropical vegetation of the lower regions at once gives place to open pine forest, characteristic of and entirely limited to the Mesozoic rocks of these higher elevations.

*The western mountain ranges.*

Kalaw itself lies in one of the narrow north and south trending valleys in the Mesozoic rocks which the main lines of drainage form in the western part of the sheets under description, and the high limestone ridge of Sintaung (6,022 feet) which crosses the south-western corner of sheet 93 D/10, is not visible from the town. Due north of Kalaw lies a ridge containing peaks 5,532 and 5,090, the continuation of the watershed already mentioned, and the separating line between the elevated uplands of the Shan tableland on the east and the rugged, deeply sculptured ranges which lie between it and the plains of Upper Burma on the west. This ridge develops a stronger individuality in the next sheet further north and has an average elevation of 4,600 feet where it marks the eastern limit of drainage of the Panlaung river and its tributary the Toklet *chaung*, and where steep descents in their deep, yawning valleys of 2,000 and 3,000 feet are common in two or three miles.

Leaving the ridges of Kalaw and Loi-an and proceeding east, the Shan tableland is encountered. It is not, as its name might appear to indicate, a level plain, for it has been compressed by stresses acting from the east into several folded and parallel north- and south trending ranges separated by eroded longitudinal valleys at various elevations between them. The tableland, or the Shan plateau, as it is usually called, differs from a normal tableland in that it possesses some of the features that are usually found in mountainous areas.

**The Shan tableland. Its ridges and old lake valleys.**

The dominating features of the country between Kalaw and Taunggyi—a distance of 44 miles—are the three plains of Thamakan, Heho and Yawnghwe, the hilly ranges which separate them, and the great platformed ridge of Taunggyi itself dominating the Yawnghwe plain and overshadowing the Inle Lake on the east.

Beyond the Mesozoic ridges of the Kalaw neighbourhood lie the downs of the Vale of Thamakan—an old dried lake-bed of Plio-Pleistocene age now undergoing active degradation. Its general elevation is about 4,100 feet and it extends from a few miles north of Legya (20° 33′ : 96° 41′) in the south to near Poila in the north (20° 51′ : 96° 41′ 30″).

It is separated from the Heho plain, another site of a lake which disappeared in more recent times, by the gently westerly dipping limestone escarpment of the Thamakan range. In size Lake Heho must have at one period approximated Lake Thamakan.

Another limestone ridge of a more complicated character and greater age separates the Heho plain from the Yawnghwe plain with its Inle Lake.

The Thamakan and Heho ranges coalesce north of Lake Heho, the Plateau Limestone of the former continuing to the west of north through Pangtara (20° 57′ : 96° 40′), where it loses elevation and fades out north of Kyauk-su (20° 58′ : 96° 41′ 30″) after forming the peak Nangontaung (4,881 feet) and the heights around Poila. The Heho ridge goes on directly north past Kyawktap (20° 5′ : 96° 46′) and then broadens out to build the highlands of Mawsōn, attaining a maximum height of 5,473 feet as it crosses into Lawksawk State.

Rising from the dissected, rugged country north-west of Poila, is the wall-like escarpment of the Pindaya ridge, composed of

Ordovician rocks. It overlooks the valley of the Zawgyi *chaung* and the Pindaya plain on the west and gains both in appearance and height further north where it attains over 6,000 feet above sea-level. It is in some respects comparable with the Taunggyi escarpment to which it is parallel, though further north and scarped to the opposite point of the compass.

Leaving the Yawnghwe plain at less than 3,000 feet above the sea, the road ascends the first platform of raised terrace deposits, some 300 feet high, before commencing the steep ascent across the face of the Ordovician limestones which build much of the Taunggyi ridge. At mile 102, before the sharp bend which leads on to the Taunggyi platform proper, the Plateau Limestones occur and they build the wall-like, easterly dipping crag (5,750 feet) rising steeply behind the town, and much of the platform itself. Taunggyi (4,675 feet) thus occupies a site on gently rising ground just behind the edge of a precipitous descent on to the lower platform on the west which borders the plain below.

**Drainage.**

The Panlaung river and its tributary in the west flow through deep, narrow, heavily forested gorges which belong physiographically to the outer western ranges rather than to the open grassy downs or the rocky limestone ranges of the Myelat to the east. The latter region is essentially *karstic* and has a highly developed underground water system, with the accompanying disappearing streams, cauldron valleys, sink-holes and caves. The direction of the surface flow of the smaller valleys is usually indeterminate and the topographical map reveals to how great an extent a normal surface drainage has been suppressed by underground flow. The drainage of the Poila valley, such as it is, is south through the Thamakan plain into the Nyansin *chaung* and Lake Inle.

The watershed between the Poila and Pindaya valleys is again the divide between the Irrawaddy and the Salween, as the Zawgyi and its headwaters of the Pindaya range and the western part of the Mawsön hills eventually reach the Nàm-Tu, while the overflow from Inle empties into the Salween *via* the Balu *chaung* (again after an underground course). The flat country on the east of the map and the Taunggyi ridge drain into Inle, the former by way of the Naling (Namlap) *chaung*.

The region between the Pindaya-Poila-Thamakan valleys on the west and the Naling valley on the east, including the whole of

Mawsŏn, is full of valleys of enclosed drainage of all sizes, the flow from which during the rainy season, for they are dry during the rest of the year, may reach one or other of the major systems mentioned, by devious channels below the surface. During the dry season it is a parched land openly displaying its long corrosion at the hand of time; running streams and springs are very rare and towns and villages outside Kalaw and Taunggyi, where British enterprise has made modern reservoirs, are alike dependent on shallow artificial storage tanks or in some cases, in the flats of the plains, on deep wells for the needs of man and beast.

A special reference may be made to the underground course of the Nyansin *chaung* through the Heho ridge. It originally flowed in a deep and narrow defile across this ridge to join the Inle Lake and the gorge still bears abundant traces of river action. Probably as a result of a landslip caused by the river itself it was diverted to its existing underground course which is quite close to the surface. The noise of its roaring water can be heard in the defile and during the monsoon flood its surplus flow breaks through caves into the open air. At one place in the defile, fishermen enter the underground passage which is stated to be passable for 200 yards before it narrows again. Where the old course leaves the defile to enter the Inle plain, thick river deposits exist composed of boulders, pebbles and travertine.

The general level of the Thamakan plain is about 4,130 feet above the sea, of the Heho plain 3,785 and of the Inle Lake 2,915 feet respectively. There is thus a progressive drop of levels corresponding to 345 and 870 feet from the first to the third. We believe that the lake deposits of Inle and the Yawnghwe valley have continued forming from Plio-Pleistocene times to the present day, that in the Heho valley their deposition ceased in comparatively recent times, while those of the Vale of Thamakan are the oldest of the series.

The Inle Lake.

The Inle Lake of to-day is about 14 miles long and about four miles broad. We shall describe it more fully as we believe it presents a picture of the hidden history of the older lakes and explains the formation of the lignite deposits which they contain. Its depth varies with the seasons. In March it is nowhere greater than 12 feet, and the average depth is not more than seven feet; but at the end of the rainy season the greatest depth must be at least 20 feet. The

present water-spread is merely a remnant of the old lake which was at least 36 miles and possibly very many more in length, with a maximum breadth towards its southern end of perhaps eight miles.

Its main water-supply comes from the north *via* the Nam Lap and from the west by the Heho stream which has a drop of over 800 feet through its narrow gorge in the Heho ridge, and by the Nyansin *chaung*. This stream rises south of Kalaw, receives the drainage of the Thamakan basin and enters Inle through a delta after an underground course through the western boundary ridge between Ngot (20° 33′ : 96° 47′ 30″) and Taung-gya.

The lake is completely surrounded by floating islands formed by the growth and decay of vegetation and massed together round its edges. According to Dr. N. Annandale, who was helped in the geological aspects of his investigations by our late colleague Captain F. W. Walker,

The floating islands of Lake Inle.

'Many different kinds of plants take part in their formation, but those of primary importance are certain large grasses and sedges that send out long floating runners from which new upright stems arise. Floating plants such as duckweed become entangled amongst these runners, and at the same time submerged weeds, especially a species of *Ceratophyllum*, grow up to the surface, where their upper parts are killed by the heat of the sun or the growth of algae. The mass of vegetation thus entangled is further agglutinated by the luxuriant growth of an alga belonging to the family Rivulariaceae which forms large brownish masses. These elements of the island in the making both decay and grow. Their decay forms a kind of fen-peat which is prevented from sinking by their floating and growing parts.

A floating island covered with rich soil is thus formed, and plants of a great variety of species grow up upon it, forming dense entangled masses. Even conspicuously flowering orchids and small shrubs flourish in a little time.'[1]

The formation of peat.

The floating islands, cultivated on in their natural state, congregate at the ends of the lake and especially near the southern end where they merge gradually into swampy land. The bottom of this marginal zone is composed of a black peaty substance. Annandale considered that the amount of peaty matter which is continually in the process of formation round the Inle Lake was enormous. He believed, and we share his views, that the peat, together with the silt brought in by the streams and, we would add, the astonishingly rapid growth of calcareous tufa deposits, must, in the end, fill up the basin completely.

In this rapid and extensive growth of aquatic and semi-aquatic plants, which in their turn quickly change into peaty deposits,

[1] N. Annandale, 'Fauna of the Inle Lake', *Rec. Ind. Mus.*, XIV, p. 3, (1918).

similar to those found about the margins of the Heho plain, we believe we have found a true clue to the origin of the lignite deposits of the Shan lake basins, and certainly a more reasonable theory than one lately advanced which would derive them from vegetation washed into lake basins in this region by great rivers of which no trace now exists, from forests in Upper Burma and Assam.

**The peat deposits are the clue to the origin of the Shan lignites.**

Even in the deepest portions of the lake totally submerged vegetation lives and flourishes though the bottom is in some places almost bare with only scanty growths

'of such plants as *Potamogeton crispus*, *P. pectinatus*, *Hydrilla verticillata* and a species of Characeae, but over the greater part of this region dense masses of *Ceratophyllum* flourish, binding the bottom together with their roots to some extent, but not sufficiently to make it solid. The submerged thickets thus formed rise up to a height of at least 7 or 8 feet, and sometimes almost reach the surface. In some places they are in a flourishing condition even when their growing parts are almost in contact with the surface film, but at others they exhibit towards their upper extremities all the symptoms of ill-health, probably because of the growth of algae of various kinds among them.'[1]

The nature of the bottom in the central portion of the lake also throws much light on certain deposits found in the Heho and other dried lake basins.

**The calcareous ooze of the centre of Lake Inle.**

'Strictly speaking', wrote Annandale again 'the lake has not a solid bottom at all. Beneath the water there is a layer of semi-liquid consistency composed of extremely small particles of a greenish grey colour suspended at a constant level, but never in their natural position becoming consolidated even into real mud. These particles are largely of a calcareous nature, as is shown by the following analysis of a dried specimen from the bottom of the northern part of the central region. This analysis also was made by Mr. R. V. Briggs :—

| | Per cent. |
|---|---|
| Insoluble siliceous matter | 0·98 |
| Alumina | 1·30 |
| Oxide of Iron | 2·25 |
| Lime | 45·31 |
| Magnesia | 1·25 |
| Potash | 0·12 |
| Soda | 0·46 |
| Moisture | 3·10 |
| Carbonic acid | 33·15 |
| Phosphoric acid | 0·17 |
| Sulphuric acid | 0·41 |
| * Organic matter and combined water by difference | 11·50 |
| TOTAL | 100·00 |

* Containing Nitrogen 0·619.

[1] *Loc. cit.*, p. 4.

'On being dried this pea-soup-like mass forms a grey, very friable clay in which fragments of vegetable matter are abundantly present.'

On the western edge of the Heho plain where the stream enters its gorge to descend to the Yawnghwe plain, it has cut to a depth of 20 feet through grey clay exactly similar to the material just described. The grey clay is also found in cuttings below the soil at the northern end of the Yawnghwe plain. These clays, like the peaty deposits, are full of shells belonging to the same genera and in many cases to the same species as the living fauna of Inle.

## LIST OF FORMATIONS.

The formations met with in our area are treated in the following order :—

| | |
|---|---|
| Alluvium and travertine . . . . . | Recent. |
| Residual deposits and upland plains . . | Sub-Recent. |
| High-level terraces . . . . . . | Pleistocene. |
| Lacustrine deposits . . . . . . | Late Tertiary. |
| Red Beds . . . . . . . . | Cretaceous. |
| Coal Measures (Loi-an series) . . . . . | Jurassic. |
| Upper Plateau Limestone . . . . | Permo-Carboniferous. |
| Lower Plateau Limestone . . . . | Devonian-Carboniferous. |
| Silurian and . . . . . . . . | |
| Ordovician rocks . . . . . . . | |

In dealing with the Lower Palæozoic, the most convenient method of description seems to us to lie in the adoption of a geographical classification in the first instance, dealing in turn with the three great inliers in which they occur. These are the Pindaya, the Mawsön-Heho-Mawnang and the Pon-Taunggyi occurrences. A tentative attempt to correlate these is given in the following table and is subject to modification in the light of the results to be obtained from a critical examination of the more important fossils.

*Tentative correlation of the rocks of the Lower Palaeozoic inliers.*

| Age. | Northern Shan equivalents. | Pindaya inlier. | Mawsön-Heho-Mawnang region. | Pon-Taunggyi region. |
|---|---|---|---|---|
| SILURIAN. | | | | |
| Upper . . . | Zebingyi stage . | .. | Tentaculites beds. | Tentaculites beds. Trilobite beds of Pon. |
| Middle . . | .. | .. | .. | |
| Lower . . . | Panghsapye band | Wabya graptolite bed. | (c) Mebyataung. (b) and other. (a) graptolite beds. <br> Orthoceras beds. | |
| ORDOVICIAN. | | | | |
| Upper . . . | Upper Naung-kangyis. | Pindaya beds . | Mawsön series . | Taunggyi Crag exposures. |
| Middle . . | Lower Naung-kangyis. | .. | .. | |
| Lower . . . | .. | .. | .. | Taung-bu, Sale and Taunggyi scarp exposures. |

## RECENT ALLUVIUM.

True river-borne alluvial deposits are scarce and occupy but a small fraction of the area. Only the larger streams carry perennial water and an occasional small spread of pebbles or a patch of clayey loam, such as those found on the banks of the Poila stream, or deep down in the Toklet valley, comprise all that can be regarded as of recent origin under this head. Such deposits are nearly always terraced and utilised for wet rice cultivation, the higher straths, if any exist, being occasionally devoted to orange gardens, as in the vicinity of Poila and Pindaya and to some extent near Kalaw. It is not intended to convey the impression that little agricultural land exists, for extensive cultivation is carried on in the lake valleys and on the dry clayey soils covering both the Plateau Limestone and the older rocks. In this part of the Shan States, potatoes are a common monsoon crop in such situations and are extensively exported both to Burma and India. Flourishing fields of other vegetables indicate that under a scientific system of artificial fertilisation and cheaper methods of transport than prevail to-day, these soils may yet prove of great value. Wheat and other cereals are also grown on the higher uplands both by Gurkha colonists and the indigenous hill-folk.

The peaty soils of the margins of the old lake basins and the grey calcareous clayey ones of their more central portions are devoted mainly to the cultivation of rice.

## TRAVERTINE DEPOSITS.

One of the most extraordinary natural phenomena to be seen in the Shan States is the extent and the rapidity of formation of tufa by the deposition of calcium carbonate from solution in water. The process is thus described by La Touche :—

'The enormous extent to which the limestone of the plateau is being removed in solution by percolating waters has already been alluded to, and it is not surprising to find that when the water comes again to the surface in springs and rivers, and is either evaporated or loses the carbonic acid which keeps the carbonate of lime in solution, the deposits should reach correspondingly huge dimensions. Indeed I doubt whether any other limestone tract can show deposits of this kind of such magnitude, at least in the open air. In the ordinary "Karst" region the evaporation usually takes place as the water trickles into the caverns and hollows worn out of the rock, with the formation of stalactites and stalagmite; but in the Shan States there are no open caverns in the great bulk of the limestone, owing to its universally shattered condition, which causes the mass to settle down as underground solution proceeds; though in the super-jacent, more compact, Permo-Carboniferous limestones caverns are common enough.[1] Thus the carbonate of lime which would ordinarily be deposited on the walls of caverns and fissures is in this region brought to the surface and thrown down in the open. The brecciated structure of the rock allows water to percolate through the mass in all directons, and this no doubt adds to the rapidity with which it is dissolved.'[2]

The only examples of the travertine dams common enough in the larger perennial streams of the States generally, occur in the upper waters of the Panlaung river, an illustration of which is given in Plate 8, fig. 1. After its junction with the crystal clear waters of the Myittha *chaung* at Songyi, the influx of pure water from an area of non-calcareous rocks is sufficient to inhibit the formation of these dams, and they do not occur in any part of its course below this point, as Sondhi found during a journey down the Panlaung on a bamboo raft, although masses of travertine cover the banks at many places.

Deep pools of any of the rivers flowing over calcareous rocks show the water to possess a peculiar, milky, greenish blue tint which may be due to the presence of suspended particles of carb-

[1] The well-known Pindaya caves of our region are in Permo-Carboniferous limestone.
[2] La Touche, *loc. cit.*, p. 325.

onate of lime. Be that as it may, the fact remains that any artificial barrier or natural disturbance quickly brings about the formation of a tufa dam even in the largest stream of this character. These take the form of weirs from a few inches to six feet and more in height and level enough along their crests to suggest the aid of human workmanship in their construction. The Shans build fishing weirs on the rapids of their rivers—rough lines of stakes driven into the beds and interlaced together by split bamboos and wattles. Within a few weeks, the leaves and twigs held by these obstructions are often bound together in a solid mass by the deposition of tufa upon them.

La Touche advanced a theory concerning the origin of the tufa dams which to our minds is not entirely convincing, but we have no alternative to offer and to it the interested reader is referred.[1]

Apart from the calcareous dams in this river, and again for the benefit of the geologically-minded traveller who is unlikely to visit the upper reaches of the Panlaung, we would state that good examples are to be seen beyond Taunggyi in the Nam Teng valley and again at Kunhing on the Nam Pāng (248 miles). Travertine is deposited on a large scale in the beds of small streams and by springs issuing from the great limestone scarps in favourable places where they are underlain by impervious rocks. In such cases then precipitous sides

'are generally festooned with huge masses depending like curtains from their crests; and where the conditions are favourable these masses may extend completely across the gorge and form a "Natural Bridge"'.[2]

Although between Kalaw and Taunggyi conditions are not favourable enough for the formation of natural bridges, great masses of travertine may be seen around and below Wetpyuye (20°42′: 96° 31′) and again on the last ascent from the Yawnghwe plain to Taunggyi about mile 41, the bed of a torrent, dry for most of the year in this neighbourhood has then every appearance of a frozen waterfall. In another place near Bawgyo in the Northern States, a railway cutting some hundreds of yards long and a hundred feet or more in depth is excavated entirely in tufa, deposited

[1] *Loc. cit.*, pp. 326-328. This deposition of calcareous tufa at points where obstructions cause the waters to be agitated finds a parallel in the deposition of a coating of psilomelane on manganiferous marbles at a waterfall at Ghogara on the Penoh river in the Central Provinces, although the detailed cause is different. See *Mem. Geol. Surv. Ind.*, XXXVII, p. 395, (1909)—L. L. Fermor.

[2] La Touche, *loc. cit.*, p. 329.

by springs issuing from the hillside above the line. Great banks and beds of tufa occur in the plains of Möng Nai and Mawkmai and to a lesser extent in the Hopong plain to the east of Taunggyi.

On the Heho plain narrow tufa ridges are to be seen running for considerable distances above the surface of the soil. They are full of shells of the same species as those occurring in the peaty deposits and are supposed to represent the beds of former streams; drying completely or reduced to a mere trickle in the summer, such streams build up their beds by the precipitation of the carbonate of lime as the water evaporates, essentially a different method of tufa formation from that of the dams in the large perennial streams.

The curious anastomosing character of the streams of the Yawnghwe plain—more reminiscent of deltaic conditions than of an inter-mountain plain, is a consequence of this raising of their bed levels, for the water then breaks away from the parent channel and, wandering across the more or less level surface, forms new lines of flow which meet and break away again, before they too in their turn perish.

The effects of rapid travertine deposition are remarkable. In the stream beds outcrops of the tough outer layers resemble older rocks until they are broken and the characteristic banded and fibrous structure of the deposit revealed. Tufa again often binds pebbles and rock fragments together into breccias and conglomerates of recent origin which may be mistaken for rocks of greater age. By the deposition of this material in small cracks and fissures of the red clay a hard, cellular, pink, argillaceous limestone is formed, its origin often betrayed by the presence of land shells and leaves.

The presence of leaf impressions of recent plants and trees in the spring-deposited travertine is universal. They are generally in perfect preservation and display the most delicate tracery of the vegetable skeleton.

The process of travertine formation can be watched and studied where the lime-laden waters drip or trickle over decaying vegetation. The carbonate is deposited in concentric layers around every twig and rootlet, the organic matter can be seen in every stage of decay until eventually nothing is left but a hollow tube, to be filled in later in the same manner. Annandale relates the discovery

at the head of the Heho pass of what at first sight to this zoologist, appeared to be fossil coral reef, but was actually a tufa bank in process of growth. Heavy rain had washed away the covering earth, and exposed the interlacing roots of vegetation. Lime-bearing waters dropping on these commenced the petrifaction—a process which invariably occurs when suitable conditions arise.

## RESIDUAL DEPOSITS.

'One of the most striking features of the plateau country',

wrote La Touche with reference, it is true, to the Northern States, but equally applicable to the Plateau Limestone areas of the country between Kalaw and Taunggyi,

'is the universal mantle of red clay, which is spread over the limestone. When one ascends even the smallest elevation above the cultivated straths that border the streams, red is the prevailing colour that meets the eye, wherever the soil is exposed, and it certainly adds much to the picturesque character of the scenery. The colour is a bright Indian red, sometimes with a slightly orange tint when dry, but becoming much darker when wet. On the open plateau the clay contains little or no sandy matter, and is of a stiff, tenacious nature, very slippery when wet with rain. It is usually filled with pisolitic nodules of iron oxide, ranging from the size of a pea to that of a hazel nut, resembling the nodules of which some varieties of laterite are built up. In fact it is not improbable that the red clay owes its origin to a process similar to that to which the origin of laterite is generally attributed, the decomposition of the underlying rock: but in this case the product is less consolidated, owing perhaps to the absence of siliceous matter from the limestones. It corresponds rather to the "*Terra Rossa*" of south-east Europe, where it is largely developed in the limestone tracts (*Karstgebiete*) Istria and Dalmatia, where however, it is usually confined to hollows in the surface and to caverns.'[1]

On the limestones of the upper division of the Plateau group the soil and clay tends to be of a more yellowish red colour and on the calcareous shales of this division it is usually a dull deep grey.

Excellent examples of the red type are seen between Kyong (20° 47′ 30″ : 96° 39′) and Poila and between the same place and Myinkyado (20° 56′ : 96° 33′). Near Kyawktap, the boundary of the Plateau Limestones and older rocks on the east can be traced by the change in colour of the soils of the two formations. In mapping the boundaries of the Thamakan lake deposits, owing to the lack of surface rocks, the colour of the Plateau Limestone clay is of great assistance. In this connection a word of warn-

[1] La Touche, *loc. cit.*, p. 322.

ing is necessary. It is the custom of local cultivators to collect the surface soil during the dry weather into small heaps around a central core of leaves, twigs and cow-dung and to calcine this by burning. When the process has been repeated for a few seasons, the lighter tinted soils of the other formations assume artificial reddish colours by reason of the oxidation of their iron contents, which by the unwary might be taken to be those of true Plateau Limestone soils.

Collecting in all situations with a gradient low enough to prevent its removal in the monsoon rains, the *terra rossa* blankets all the lower portions of the Plateau Limestone area, assuming a smooth and mature appearance which is entirely misleading as to the condition of the underlying rocky surface. The latter, though rarely seen, is corroded and confused beyond description, so that while one limestone pinnacle may almost reach the surface, a few feet away there may equally well be a clay-filled hole 30 or 40 feet deep. In this part of the Shan States as elsewhere, the insoluble iron compounds, the concentrated products of hundreds of feet of rock decay, tend to segregate into pisolites and small nodules scattered through the clay or confined to ill-defined zones in it. Thin surface deposits of limonite 'beans' sometimes accumulate in little rivulets which gather the surface water together for the larger drainage channels in the wet weather, but nowhere have we seen the iron compounds segregated into the irregular spreads of good iron-ore which sometimes lie between the *terra rossa* and its parent rock in the Northern States and are of considerable economic importance there. This is not a sufficient reason to conclude that they do not exist, for complete sections are very rare.

## THE UPLAND PLAINS.

The geological map accompanying this report shows a number of areas of residual deposits which are best described as upland plains. As typical examples the one extending north from Kyawktap to Thegon and thence west to Ta-me, or the long area stretching north from Pindaya, or the parallel one between Thitebin and Gwe-bin, three miles further east, may be quoted. Some of the smaller plains contain lakes, as in the case of Twin-su, or the three-armed valley of Baw-lon (20° 54′ : 96° 48′). The smaller examples, which all lie in valleys of enclosed drainage, may have originated through the blocking of the funnels leading to the

underground water circulation system, and the earlier existence of lakes in some of the larger ones—apart from the artificial collections of water in large tanks behind earthen dams, a device of the local people for storing water during the dry season—is suspected but not proved. They are not perfectly flat plains except in their central portions, for the gradual downward creep of soil and clay from the surrounding hills results in the imperceptible merging of gently sloping eluvial deposits, which are but little removed from their original situations, into stuff which has probably been transported from greater distances. The approximate general elevation of the larger upland plains is not much below 4,000 feet. With the exception of a layer of cream-coloured silt underlying the red soil in a stream bed half a mile north-east of Pindaya, nothing but red soil and clay has been seen in them.

## HIGH-LEVEL TERRACES.

At the foot of the Taunggyi range there is a well-marked platform of pebble beds and sandy clays bordering the Yawnghwe plain on the east and stretching for three miles from Thitpindaung to Kônbeau, near Salē (20° 47′ 30″ : 96° 58′ 30″) where it becomes reduced to a mere tongue stretched out to the east along the bottom of the precipitous ridge above. The flat top of this platform is over 300 feet above the level of the Yawnghwe plain and the pebbles which it contains were derived from the Silurian sandstones of the ridge to the N. N. W.

**Comparison with high-level lake and river terraces elsewhere.**

Now raised terraces of this kind and of both fluviatile and lacustrine origin are known from many places in the Shan States and adjoining regions. Thus for example at Mogok, there are the old gem-bearing lake gravels, the base of which is above the level of the present alluvium; in Mainglong there are terraces, 200 feet above the level of the existing Nampai river, which Nœtling thought were lake deposits. The old river terraces of the Nam Tu near Hsipaw have been described by La Touche and their growth is held to be responsible for the peculiar course now taken by that river above Hsipaw. At the mouth of the Nàmhsim, a tributary of the Nàm Tu, the existing remnants of old terraces are over 100 feet above the present river level. Further afield in Yünnan, they have been described from many of the valleys by practically every geologist who has visited the province. In the Salween valley

there, they attain heights of over 300 feet above present river-level. So widespread are these deposits in Yunnan that W. Credner devotes a special development phase of tectonic origin to them in his recent classification of Quaternary events, and describes it as Diluviale 'Aufschüttung in Talern und Becken'.[1]

These examples are quoted here to prove that our lake and terrace deposits are not merely local developments and that their origin should not be sought in circumscribed events within limited portions of the Shan States but in great earth movements on a continental scale.

It has been held by some writers that pebble beds such as those of the Yawnghwe terrace are too coarse to have been deposited on a lake bed, but it seems to us that while the clays and sands may be true lacustrine deposits, the pebble beds may equally well represent torrential, rudaceous collections carried down into the lakes during times of flood.

Similar deposits form the elevated ground at the head of the Yawnghwe valley to the west of the Namlap *chaung* and between it and the eastern wall of the Mawsön highlands about Sinchaung and also they build up the elevated rolling ground bordering the Kun-lon valley on the north-east.

In the extreme north-eastern corner of our area raised terraces are again encountered in the valley of the Nam Akye, east of Nawng-yun (20° 57′ : 97° 16′), where perfectly rolled pebbles and boulders are to be seen some 200 feet above the present level of the stream. Three miles to the north the village of Kōnlōng (21° 0′ : 97° 11′) is built on such a deposit and stands nearly 150 feet above the stream-level.

Here the boulders are unusually large and are mostly of hard, quartzitic sandstone, derived from rocks of the same description, covering this portion of the area, and believed to be representatives of the Coal Measures.

## LACUSTRINE DEPOSITS.

These lake deposits range from the Plio-Pleistocen‸ sands, clays and silts of the former Thamakan Lake, through the sub-recent clays which underlie the Heho plain, to the deposits of the Inle Lake, which are still in process of formation to-day. They

[1] W. Credner, 'Yünnan Reise', II, *Mitt. Geog. Inst. Sun-Yatsen Universität.*, Kanton, Bd. I, Nr. 2, p. 91, (1931).

are not confined to the region under discussion, but appear to occur in many parts of South-Eastern Asia where conditions have been favourable to their origin. They are all of comparatively young origin and are found in detached basins, occupying existing river valleys at all kinds of elevations from Siam, and Indo-China through the Southern and Northern Shan States into Yünnan.

In the Northern Shan States they happen to be mainly confined to the portion of the plateau surrounding the high ground culminating in Loi Ling; but it is necessary to draw attention to their wide distribution in other regions in order to combat a recently advanced theory of a series of lakes or a large single lake extending southward in a great hypothetical depression east of the main Shan plateau. This depression, according to C. S. Fox,

'lay roughly parallel with the geosynclinal of the Irrawaddy valley, which lies west of the Shan plateau. The general compression and uplift, which was already in progress in Miocene times, would account for the origin of the Shan lake basin as another synclinal. Judging by the occurrence of Pliocene and Pleistocene deposits in upper Assam and northern Burma, it is possible that some of the drainage from these regions discharged into the Shan lakes. And seeing that the Irrawaddian and Tipam sediments are often characterised by the presence of lignitic and silicified tree trunks, it is not improbable that vegetable debris from the same forests were swept into and settled in the quiet waters of the Shan lake and were there transformed into lignite.'[1]

We do not propose to criticise this theory here, beyond pointing out that we do not agree that there is any evidence that a large Shan lake existed, or that the drainage from Upper Assam and Northern Burma reached the Shan States in Plio-Pleistocene times.

Occurrences of lignite are not confined to the lake deposits of the Northern Shan States, they are found also in the Southern Shan States and in Siam and Yünnan. In eastern Amherst, Tavoy and Mergui, the lake basins contain oil-shales and lignites of more or less contemporary origin with ours.

The causes which have brought about the draining of certain lakes are of both local and widespread origin. Under the first head we include the gradual filling up of a basin with sediments aided in some cases by widespread deposition of thick tufa deposits, or its emptying by the cutting back of its overflow channels through the solution of limestone.

In this connection it is interesting to note that the drainage channels of the lakes usually discharge through limestone. In

[1] C. S. Fox, *Mem. Geol. Surv. Ind.*, LVII, p. 205, (1931).

searching for the original cause of the lakes themselves a clue is found in the existing valleys of enclosed drainage in limestone areas. By the accidental blocking of the inlet to the underground drainage system of one of these, a lake is immediately formed and instances are known where small lakes, both natural and artificial, have been created in this way, though tectonic causes have admittedly played their part in the creation of the large ones.

Deposits of Lake Thamakan.

The deposits of the old Thamakan Lake now occupy an elongated elliptical area 15 miles long and about half that distance in maximum width. They are surrounded entirely by Plateau Limestone except in the south-west where they abut on Jurassic rocks. The lacustrine deposits are often severely crumpled by movements of the limestone floor as a result of solution. Apart from these purely local disturbances, the sands, sand-rock, loose pebble beds, soft conglomerates, silts, clays and loams of which they are composed are usually horizontal or possess dips of low angles conferred on them by warping movements during the general elevation of the whole country. Exposures are infrequent, as is only to be expected, and are best found either in natural stream sections, which are uncommon, or in road and railway cuttings. Approaching Aungban from Kalaw and looking across the narrow paddy plain to the north just before the town is reached, a low cliff is visible, stained and splashed towards the top with red and brown ferruginous products and corroded deeply into a group of 'rain pillars'; these are typical Thamakan deposits.

The crushed and distorted, soft, yellow and yellowish-red sandstones which occur in the limestone, just to the south of Kyong, are further examples. Just to the south of the village and also about half a mile north of it, the road has been cut along the western limits of these deposits. In a few well-displayed sections in the road cuttings hereabouts the soft deposits are seen filling angular V-shaped hollows and chimneys between sharp pinnacles and 'dog-teeth' of the Plateau Limestone, presenting a fair picture of the highly serrated profile of the latter rock formation at the time it was submerged under Lake Thamakan.

According to Middlemiss outcrops of lignite occur among the sands and clays in a horizontal layer at a point half a mile south-west of Nan-gon (20° 48' : 96 °42' 30") and also at another place in the same neighbourhood 1¾ miles west by south of Nan-gon. To him

it seemed probable that a more or less continuous layer exists, though neither very pure nor very thick.

Indeed since 1887 it has been known that beds of lignite are sometimes found in the old lake basins of the Southern Shan States.

Lignite occurrence in the old lake basins.

These are mentioned by E. J. Jones (1887), as well as by Middlemiss (1900), as occurring in the Tigyit valley, and there is little doubt, owing to their common origin, that boring in suitable positions would reveal their occurrence in other lake basins, where at present they are unknown, because nothing is visible in them but the recent surface covering—very often a deep black, carbonaceous soil largely composed of vegetable debris and of the nature of peat.

Lignite-bearing rocks of Pleistocene age are well known in Northern Siam, Tonkin and the Malay Peninsula. Wallace Lee, describing the former, states that they occur in isolated topographical basins, exactly as the Shan ones do:—

'The relief of such areas is low, and most of the rocks are exposed in the mountains on the margins of arable basins. The rocks consist of shale, fire-clay, coal, thin sheets of limestone crowded with fresh-water fossils, and subordinate amounts of sand. In spite of the fact that these beds are nearly always steeply inclined, they show a very small degree of metamorphism. The coal beds, some of which are more than 6 feet thick, are impure and have not progressed beyond the stage of lignite. On account of the decomposition and limited exposures, it was never possible to measure a full section; but these beds are at least 200 feet thick and probably much thicker. They are probably lake deposits formed in basins of post-Tertiary disturbances, probably associated with faulting. Similar deposits have been observed by French geologists as far north as Tonkin, where their age is considered Tertiary.'[1]

## THE KALAW RED BEDS.

The hill-station of Kalaw is built on a deposit of arenaceous shales, sandstones and coarse conglomerates. Except for the conglomerates, which, when fresh and rich in limestone pebbles, are grey, a persistent brick-red colour pervades the entire deposit.

In our area there are three outliers of these beds, the first in the south-west portion of our map occupies a long, narrow N. N. W.-S. S. E. basin in the Coal Measures (Loi-an series) on which they are unconformably deposited, and carries the main Thazi-Kalaw road between Kyatsakan, 34 miles from Thazi, and Kalaw, as

[1] Wallace Lee, 'Outline of the Geology of Siam', *Bull. Amer. Assoc. Pet. Geol.*, XI, Pt. 1, p. 411, (1927).

well as about eight miles of the railway line south of the latter town. The second and third to the north were doubtless connected until denudation removed them in the neighbourhood of Legaung, where small detached patches still survive.

**Section of the main Thazi-Kalaw road.**

Several very good sections of the different members of the Kalaw Red Beds are visible along the road in the Taungwindwin valley and were originally described by Middlemiss. This stream has cut a well-defined deep course along the strike of these rocks. The conglomerates, which form perhaps the most remarkable feature as well as the greater bulk of the formation, are of varying texture, compactness and composition and occur at different horizons. The narrow, sharp ridge along the valley on the east is formed of a coarse conglomerate band containing large boulders of hard, purple sandstone and smaller ones of limestone, embedded in a red, sandy calcareous matrix. And the high, rugged hill-range flanking the valley on the west is built for the most part of a coarse soft conglomerate remarkable for the large size and angularity of its sandstone boulders and the low proportion of its calcareous contents.

A study of dips, seen only in the shale and sandstone interbeddings, indicates a gentle puckering of the beds.

**Exposures near Kalaw.**

Excellent exposures of the Kalaw Red Beds are to be seen about Kalaw itself, in the railway cuttings between Myindaik and Kalaw and along the main road to Thazi for some miles. Kalaw lies at the bottom of a well-defined synclinal valley. A thick band of grey, compact calcareous conglomerate that crops out at the Railway Station and builds up the great sharp range running due south of the town appears again on its western suburbs. From the soft, friable, reddish purple sandstones and shales, dipping westwards at about 25° in the small hillock, crowned with a pagoda, between the Railway Station and the Kalaw Hotel, Dr. Fox obtained ammonites of Cretaceous age and thus substantiated Griesbach's opinion on the age of similar rocks in the Northern States. These are the only fossils which the Kalaw Red Beds have as yet yielded, and they are discussed in a later chapter.[1]

Near Loi-an, the railway section after exposing beds resembling the lower shaly zone of the Coal Measures, shows a small outcrop

[1] C. S. Fox, 'The Occurrence of Cretaceous Cepalopods in the Red Beds of Kalaw', *Rec. Geol. Surv. Ind.*, LXIII, pp. 182-187, (1930).

of Plateau Limestone girdled with reddish earthy beds and red sandstones; a furlong or so further on red conglomerates and red pebbly sandstones are found, and good exposures of these occur in the Railway Station yard. They consist of rolled pebbles of Plateau Limestone and of red sandstone in the red sandy matrix, and the sands between the conglomerates are full of similar but smaller pebbles. Along the railway south of Kalaw red and purple sandstones and friable reddish shales occur, the sandstones of this section being better banded than elsewhere. Between Kalaw and the reservoir, four miles to the south-west, which supplies the town with water, varied sections of these rocks occur, but the reservoir itself lies on banded sandstone and shales of the older Coal Measures.

Through the solution of their calcareous contents the conglomerate bands occasionally give rise to shallow caves, perhaps the best example of which lies on the Golf Course of Kalaw where it is marked by a cluster of small pagodas.

**Section in the Panlaung valley.**

The general characters of this deposit in the other two areas towards the north are much the same. The harder conglomerates form the high peaks like Taungma, 4,469 feet (20°48′ : 96°32′30″). North of Singu the Red Beds occupy the greater part of the Panlaung valley, between the high ranges of the Myindaung and Myinbondaung (20°52′ : 96°28′) on the east and west respectively, but exposures are rare and poor owing to the thickness of soil and jungle. The high hillmass of Pandaung between these two ranges is composed of indurated conglomerate.

The only known occurrence of limestone in the Kalaw Red Beds, is a thin band found in the latitude 20° 55′, at a point due south of Kolon (20°57′ : 96°29′.).

**Intrusive igneous rocks in the Kalaw Red Beds of the Panlaung valley.**

Of unusual interest are the two tongues of igneous rocks intrusive into the Red Beds on the western side of the narrow Panlaung valley. The main mass of this consists of a coarse, pinkish porphyry with kaolinised phenocrysts of felspar sometimes half an inch in length and with a holocrystalline groundmass consisting mainly of laths of the same mineral, often wrapping round the larger crystals. The rock is itself intruded by a fresh, dark dolerite in which the majority of the phenocrysts are augite with minor crystals of felspar and hornblende, all present in almost

perfect crystal outlines. The groundmass in this rock is composed of all these minerals with a fair amount of partly devitrified glass.

In the extreme north-west corner of our area similar dolerite intrudes the Plateau Limestone, but the country hereabout is so covered with soil and thick jungle that the contact phenomena and the other igneous rocks that may be present are effectively obscured from view. Indications of thermal metamorphism of the limestone and the presence of some acid rocks are, however, sometimes met in the stream-beds where rolled pebbles of marble or of a highly decomposed igneous rock showing crystals of quartz and muscovite may be picked up.

**Examples south of Kalaw.**

South of Kalaw the Red Beds stretch far to the south beyond the limits of sheet 93 D/10. According to Middlemiss, at and to the south of Min-ywa, a locality which lies to the south of the area under description, much of the hillside east of the valley is thickly strewn with blocks of conglomerate, which is often so full of limestone pebbles that petrologically it is a limestone-conglomerate.

'Near Min-ywa', he wrote, 'also there were good examples of interstratification of it with the normal purple sandstone, so that no doubt whatever exists as to its connection with them. It would appear almost as if the much brecciated limestone had become disintegrated under weathering and the fragments flung down as a heterogeneous scree-material among the then forming purple sandstones. South-south-west of Min-ywa on the west side of the valley, great hills of what appear to be limestone reveal on visiting them (during a cross-traverse to Tigyit) nothing but huge crags and grotesque masses of this conglomerate, which again on the western slopes overlooking the Tigyit valley are found inter-banded with the purple sandstones. Even more grotesque are the strange pinnacles and "stacks" of this rock as seen some miles further south in the rugged and jungle-covered country east-north-east of Nanpale.'[1]

**Age of the Kalaw Red Beds.**

Although Middlemiss differentiated the purple sandstones and shales of the Red Beds proper from the pepper-and-salt sandstones and shales with coal, he regarded them as one continuous series, a single stratigraphical unit and at first he unhesitatingly put them down as of Tertiary age, particularly because the dark brick-red and chocolate-purple colours of the former very greatly resemble the Kasauli and Murree beds of North-Western India. On comparing his specimens of conglomerate and purple sandstone, however, with others collected contemporaneously by Messrs. La Touche and Dutta in the Northern States, it appeared to him as almost certain that

[1] *Loc. cit.*, p. 146.

they were identical and doubts of the Tertiary age of the rocks at once arose in his mind.[1]

Much controversy raged around the question of the age of the Northern Shan States Red Beds in the early years of the mapping of their boundaries, between 1899-1901. This was finally settled by C. L. Griesbach's prophetic pronouncement, for it was made before the fossils which occur in the limestones of the lower part of the series had been diagnosed.

'Certain red shales (with limestones and sandstones) formerly doubtfully supposed to be jurassic, which are considerably developed west of Thebaw' (Hsipaw) '(near Nàmhsim and neighbourhood) have now been demonstrated to be mesozoic, probably either upper jurassic or lower cretaceous.'[2]

**Age and subdivision of the Namyau beds.**

The Namyau beds of the Northern States, as they are now termed, are dark red to purple shales, clays and sandstones, sometimes with a basal limestone conglomerate and often containing thin but persistent bands of fossiliferous limestone, the brachiopods from which according to Buckman indicate a Middle Jurassic age from Great Oolite to Cornbrash.[3]

Buckman thought it advisable to divide the Namyau series into two parts—a lower one to be termed the Namyau limestones and an upper part the Namyau shales—because while there is faunal proof for the age of the former, there is, at present, none for the latter. He wrote as follows :—

'It may be that they are two quite distinct formations, differing considerably in date. It may be that the Namyau Shales are not sequential on the Namyau Limestones--that the deposition of the Limestones there may have occurred the main synclination, ........ antecedent to the time of the deposition of the Namyau Shales.'[4]

This opinion and the earlier one of Griesbach as to the Cretaceous age of the beds received confirmation through the discovery by Dr. Fox in 1929 of ammonites in the Red Beds at Kalaw, which Dr. Cotter has identified provisionally as *Turrilites* sp. *cunliffeanus* (?) and *Baculites* sp. *vagina.* Cotter has no doubt that these are related to forms from the Trichinopoly beds of the Coromandel Coast which are Upper (Ariyalur) to Middle (Utatur) Cretaceous in age.[5]

[1] C. S. Middlemiss, *loc. cit.*, p. 144.
[2] C. L. Griesbach, *General Report, Geol. Surv. Ind.*, 1901-02, p. 25.
[3] S. S. Buckman, 'The Brachiopods of the Namyau Beds', *Pal. Ind., N. S.*, Vol. III, Mem. No. 2, p. 4, (1917).
[4] *Ibid.*, p. 215.
[5] C. S. Fox, *loc. cit.*, p. 184,

Red beds of Mesozoic age cover vast expanses in Western China, French Indo-China and Siam as well as in the Shan States. From red beds near Luang Prabang in the Laos a fragment of a skull of *Dicynodon* seems to indicate a Triassic age for them there.[1] On the Korat plateau of Siam, unfolded, horizontal red beds lie unconformably on older folded varieties. Bertil Högbom and Wallace Lee attribute a Triassic age to these, but according to W. Credner they belong to the younger Mesozoic and middle to late Tertiary respectively.[2]

**Red Beds in South-Eastern Asia generally.**

In Yünnan the same authority divides the Red Beds into two discordant series: one an older folded formation, probably thousands of metres thick, to which a later Mesozoic age is ascribed; and a younger undisturbed Tertiary series, quite probably of late Tertiary age.[3]

The palæontological evidence from limestones which occur near the strongly folded Red Beds in Western Yunnan, supplied by fossils collected by Coggin Brown, indicates according to Dr. Cowper Reed, an Upper Jurassic age which he would apply also to the Lower Namyaus, as they are regarded as belonging to the same stratigraphical horizon.[4]

Finally, the lower portion of the well-known Red Beds of S'su-chnan, the Tselintsin series, are of Lower Cretaceous age, according to the determinations of Dr. A. W. Grabau, while both the lower and upper divisions of this great formation have been harmoniously affected by comparatively young folding where the Red Basin of S'su-chnan borders the frontal ranges of Eastern Tibet.[5]

These references are given here to show that the geologist working in the Southern Shan States, where great spreads of undescribed Red Beds occur, is liable to be called upon to deal with a group of rocks which may be of any age from the lowest Mesozoic to the Tertiary. It remains to add that in the region under discussion, the older unconformable Coal Measures have been far more strongly

[1] J. Repelin, 'Sur un fragment de Crane de Dicynodon recueilli dans les environs de Luang- Prabang (Haut-Laos),' *Bull. Serv. Geol. de l'Indo chine*, XII, Fasc. II, (1923).

[2] W. Credner, 'Yünnan Reise des Geographischen Instituts der Sun-Yatsen Universität, 1930', II, 'Beobachtungen zur Geologie und Morphologie', p. 52.

[3] *Ibid.*, p. 89.

[4] F. R. Cowper Reed, 'Notes on some Jurassic Fossils from the Shan States', *Rec. Geol. Serv. Ind.*, LXV, p. 186, (1931).

[5] Arnold Heim, 'The Structure of Minya Gongkar', *Bull. Geol. Soc. China*, XI, No. 1, p. 38, (1931).

affected by folding, often of the severest character, than the Red Beds above them and that the numerous persistent and strongly developed conglomerate horizons within the Red Beds themselves in our area, as distinct from the single basal conglomerate of the Lower Namyau, may indicate internal stratigraphical breaks of far greater magnitude in time than has hitherto been suspected.

## COAL MEASURES (LOI-AN SERIES).

These rocks were first studied in detail by Dr. Cotter near Kalaw in the course of the examination of the Loi-an coalfield in 1922. He distinguished the two rock formations present there as :—(1) Coal Measures, consisting of pepper-and-salt sandstones and shales with seams of coal, containing a flora of Middle Jurassic age and thus contemporaneous with the Namyau beds, and (2) the purple and red sandstones and conglomerates (Red Beds). Dr. Fox, who visited the Loi-an coalfield in 1929, gave the name of Loi-an series to Cotter's Coal Measures.

These rocks are confined to the western portion of our area, except for an exposure in the north-eastern corner, and are well developed where the Shan plateau begins to break up into a series of long, narrow hillranges, separated by deep defiles, that cover the ground between the plateau and the Irrawaddy plain.

**Coal Measures east of Kalaw Red Beds (sheet 93 D/9).**

It has been observed before that the Kalaw Red Beds were deposited in a basin of intensely folded Coal Measures. East of the Red Beds these rocks form a long narrow belt studded with patches of Plateau Limestone inliers. North of latitude 20° 45′, they build up the portion of the Legaung ridge falling in our area, with the exception of a narrow band—broken in a few places—of dolomitised Plateau Limestone along its crest, and the greater part of the Toklet valley stretching in bands of 3 to 3½ miles across through the Wetpyu-ye reserved forest, north-west into the main Panlaung valley, a distance of 13 miles as the crow flies.

This formation, as well as the succeeding one of the Red Beds, lies to the west of the plateau proper at considerably lower elevations. It is deeply dissected by torrential streams and is clothed with thick forest of a semi-tropical character. It is a very inaccessible and an almost uninhabited territory. In the middle course of the Toklet *chaung*, however, there is a narrow valley of alluvium which supports the two small villages of Legaung and Singu (20°51′: 96°29′30″).

Their communication with the outside world is by means of a narrow footpath to the 36 milestone of the Thazi-Kalaw road. It enters sheet 93 D/9 with an unnamed stream and follows the boundary of the overlying Red Beds for a little way to the north-east. Although huge blocks of Red Bed conglomerate strew the path, yellowish buff sandstones with hard clay partings and impure bluish grey limestone of the Coal Measures occur occasionally.

**Coal Measures west of the Red Beds.**

The Red Beds of Kalaw are bounded on the west by another strong belt of the Coal Measures running in the same general direction of N. N. W.-S. S. E., and the crest of the system of sharp hill-ranges forming an important local watershed here forms also the boundary between the two rock formations.

Here the component rocks are hard fine-grained shales. Excellent sections are seen in the deep railway cuttings between the railway stations of Sintaung and Myindaik, particularly between the two tunnels near the highest levels crossed by this branch of the Burma Railways. Here strong vertical beds of hard sandstone with intercalated buff and black shales occur several times. Denudation usually reduces the splintery shale to a crumbling powder which collects at the base into a soft scree deposit, leaving the beds above in strong relief. Near the eastern tunnel a sharp recumbent fold is seen in the vertical bedding, which breaks into a thrust-fault along the upper limb of the fold. The displacement is only about three feet and even less near the fold, but it illustrates the nature and intensity of the earth-movements prevailing at the close of the Coal Measure period. No such structures are found in the Red Beds that overlie these rocks unconformably. On the other hand the intensity of the movements affecting the latter deposits was hardly sufficient to warp them into gentle folds.

Towards the western limit of this belt the Coal Measures are interbedded with a few bands of grey limestone of which three are fairly strong and persistent. They are for the most part quite pure, massive and tabular, so similar to certain types of the Plateau Limestones that at places where both are exposed close together it becomes a matter of great difficulty and speculation where to draw the boundary between the two, unless of course, interbedded shale stamps the rocks as Coal Measures.

The only fossils so far obtained are some tiny specimens of *Estheria* sp. and impressions and casts of a small unidentifiable brachiopod, from the shales.

The boundary between the Plateau Limestones and the Coal Measures passes through the railway station of Sintaung and continues in the N. N. W. direction along the bottom of the deep valley starting from this point. On the west the valley is well hemmed in by towering crags and sheer precipices of the Plateau Limestone, carrying the section of the railway with its four reversing stations between Lebyin and Sintaung. On the east the hill-slopes, though steep, are really the dip-slopes of the limestone bands of the Coal Measures and the topography is comparatively more rounded.

South of Sintaung the boundary takes a sudden short turn to the east before it resumes its S. S. E. direction, and passes at the foot of the Plateau Limestone scarp of the Sintaung hill-mass 6,022 feet.

**Diorite intrusion and mineralisation of the limestone bands.**

The northerly continuation of the limestone bands of the Coal Measures form the western slopes of the Mwe-daw hill-mass, where they are highly altered and mineralised by igneous intrusions. A continuous exposure of propylitised diorite, traversed by aplite veins, is traceable from a point south-east of Mwe-daw to the village of Law (20°41′30″: 96°27′30″) a distance of about four miles as the crow flies. It is generally exposed in ravines and depressions where the overlying beds of altered limestones have been removed by denudation. The highest levels at which the rock is found are near Mwe-daw and generally speaking the elevation drops off to the north, and the difference in the altitude of the outcrops as traced to the north appears more to represent the original contours of the intrusion than merely a result of differential denudation.

The rock is holocrystalline, medium-grained, and made up mostly of felspar and ferromagnesian minerals with visible impregnations of pyrite at many places. Under the microscope the rock shows well developed porphyritic structure. Phenocrysts of plagioclase show in some cases beautiful zoned structures and contain cores of saussurite, and along the margins a granular mixture of the felspar and quartz with platy crystals of hornblende is present, with some of the latter turned to chlorite. Pyrite occurs in spongy crystals and larger patches surrounding and penetrating the hornblende and chlorite.

Boulders of similar rocks are very common in the stream at Nampandet (20°45′: 96°29′30″) and its tributaries on the east and the rock was found *in situ* at a point about two miles east of the

village in the tributary named as North Buba *chaung* in the large scale forest map. It is certain that it continues to the south towards Wetpyu-ye (20°42′ : 96°31′) as boulders of the rock are present in the South Buba *chaung* east of Kwe-ma-sa.

In addition to diorite, typical biotite-granite was found about half a mile north-east of Mwe-daw. There must have been a good deal of silica solutions associated with the intrusions to silicify the limestone bands and the interbedded shales to such an extent as they have and it is believed that this solution served as carrier for gold and copper-ore present in the altered limestones. The latter rock is either completely silicified and accompanied by wollastonite or it has turned to marble, sometimes of a very pure variety.

Another small outcrop of diorite has been observed near the village of Pangmi (20°35′: 96°42′) where again the Plateau Limestone has been turned into marble of a varying texture and purity.

Coal Measures of the Legaung ridge.

At the parting of the ways for Singu and Legaung and following the latter up the southern branch of the stream, pepper-and-salt sandstones with partings of dark shale and clay containing coal occur, while further up the ridge, before the Plateau Limestone is reached, stout regular walls of sandstone dip E. N. E. at 65°-70°. In a small overhanging valley are many small pockets and lenticles of very crushed, powdery coal. Half a mile further east shales are bedded with yellow, argillaceous sandstones and a little further up still, with comparatively thin bands of argillaceous limestone crowded with fragmentary remains of *Alectryonia* sp. and crinoid stems. The shells are too firmly embedded in the rock for extraction and in spite of a hard search no weather-loosened specimens were found, nor did roasting the rock bring any success. Rarely, however, a weathered boulder will display a complete shell of *Alectryonia* sp. sticking fast to the rock. Just before the crest of the ridge is reached dolomitised Plateau Limestone is encountered. Beyond the dolomite come yellow shales, thick and heavy, followed on the eastern slope of the ridge by black shales dipping west at about 45°. Further down the slope towards Legaung, exposures are poor and infrequent but there is evidence of the occurrence of light yellow shales below the soil.

East of Singu the sandstones dip 70° west and are found again to the west of this village at the foot of the ridge before the Plateau Limestone band is met with along the Singu-Thazi road footpath.

The Coal Measures are exposed just west of the top of the ridge dipping E. N. E. at very high angles. In places the rocks are vertical; coarse iron-stained, pink and light brown sandstones are the commonest types and further to the W. S. W., and apparently on the same strike as the occurrences of the Legaung footpath, are the same impure fossiliferous limestone and an outcrop of coal.

Coal occurrences in this area.

Details of further occurrences of coal may be given here :— (*a*) 3½ miles further north, as the crow flies, and three-quarters of a mile in a straight line from Minbondaung, a peak of the Legaung ridge, 3,106 feet high. (*b*) One mile N. N. W. of (*a*) and half a mile south-west of the confluence of the Toklet *chaung* with Panlaung river. Here the coal occurs in carbonaceous shales and dark clays inter-bedded with the normal coarse-grained sandstones. A little to the south the shales and clays contain numerous very fragile plant fossils. The dip here is to the E. N. E. but reverses to the W. S. W., a few yards further west.

(*c*) Following the same strike northwards, the next occurrence is a mile away in a straight line on the northern bank of the Panlaung river, one furlong east of boundary post No. 233 of the Panlaung reserved forest. The total width of the shales and clays is here only 45 feet. A little further north, still along the same strike, two more exposures occur, the northernmost lying in the narrow stream bed just south of the reserved forest boundary. At this place dark shales and thick beds of clay are associated with fine-grained sandstones. The strike is N. 30° W.–S. 30° E. and the dips almost vertical, with but a slight inclination to the W. S. W.

Although these coal outcrops of the Legaung-Panlaung region occur approximately on the same strike, it is far from probable that they form a single continuous seam. Their disposition, even in the limited sections visible, emphatically suggests that the coal occurs in pockets, streaks and lenticles of variable sizes. The only occurrence in our opinion worthy of any further attention and prospecting is the one which is located 1½ miles south of Legaung and one quarter mile up the ridge from point 2,638 of the map, south-west of Nanyin (20°49′: 96°30′). At this place the coal is associated as usual with shales and hardened clays and three exposures are bared within a distance of half a mile along the same strike, and apparently of the same seam. The dip here is 45° west or slightly north of west.

The prevailing rock type of the Coal Measures on sheet 93 D/9 is a light-coloured, quartzitic sandstone of varying texture. It is often iron-stained and on weathering yields a sandy lateritic soil with pisolites of iron-ore.

The small outlier of this rock formation exposed in the north-east corner of our area, in sheet 93 H/1, answers to the same description. Here the shaley contents have been reduced to a very small proportion indeed.

According to C. S. Fox,

Marine origin of the Coal Measures.

'The only important coal fields of Upper Gondwana age, (largely Jurassic)' in the Indian Empire 'are those of the Southern Shan States northwards from near Kalaw. No marine fossils have been found in these beds, which are probably fresh-water deposits, possibly accumulated in lagoons.'

Or again,

'The Loi-an coal measures near Kalaw in the Southern Shan States have been proved by their Rajmahal flora to be of Lower Jurassic age and may be lagoon deposits. No fauna of any kind has been found in these beds. The plant fossils however indicate an horizon that must be very close to that of the marine Namyau beds of the Northern Shan States.'

Or again,

'The Liassic (Jurassic) coals of the Southern Shan States (Loi-an series) may be marine, but there is no fauna to confirm this and the evidence might quite easily indicate that they are brackish water or even fresh-water deposits.'[1]

The association of limestones containing crinoid stems, and *Alectryonia* sp., etc. mentioned earlier finally settles this matter. We do not agree with the description of these and similar occurrences as 'an important coalfield'.

The Coal Measures of sheet 93 D/10.

The band of these rocks already described stretches across sheets 93 D/10 and 14 in the same general direction, splitting into several tongues with intervening wedges of Plateau Limestone, from the neighbourhood of Myinka (20°40′ : 96°35′) until the limit of the sheet is reached south of Legya (20°33′ : 96°42′). Outcrops of coal-seams have been found at intervals south-eastwards from Myinka, through Nanon, four miles S. E. by E. of Kalaw and Inwun, six miles south-east of the same place as far as Kon-hla (20°32′ : 96°40′).

[1] C. S. Fox, 'The Natural History of Indian Coal', *Mem. Geol. Surv. Ind.*, LVII, pp. 47, 33, (1931).

The most convenient locality for examining the Coal Measures is on the main road from Kalaw to Taunggyi, where they commence below the Red Beds at about mile $60\frac{3}{4}$. This outcrop is separated from the main Loi-an exposures by a Plateau Limestone barrier, otherwise they continue nearly up to mile 64. To the east of this again, another limestone band separates them from the last exposure of the series, which forms the edge of the Aungban plain.

The rocks consist of 'pepper-and-salt' sandstones and of light blue and grey shales and shaly sandstones.

Dr. Cotter has divided the rocks of the Loi-an neighbourhood into three zones, a lower shaly, a middle sandy, and an upper coal-bearing zone.

**Lower shaly zone.**

The beds of the lower shaly zone are best exposed in the railway cuttings as bands of arenaceous shales from two to six feet thick alternating with sandstones from one to two feet thick. The former are of a light blue-grey colour weathering in reddish buff tints, usually with shaly parting but sometimes more correctly described as clays. The sandstones are of a light cream to pale pink colour when fresh, of a fairly fine grain, and well laminated. No signs of coal or carbonaceous shale have been detected in these rocks.

**Middle sandy zone.**

In the middle sandy zone, the best sections of which are in the railway cuttings and along the Loi-an–Kyauk-tan road, more massive sandstones predominate. They are of a whitish-yellow colour and especially near their junction with the upper coal-bearing zone are smashed by a multiplicity of joints. Pebble beds occur and may be seen at mile 371-8 on the railway. Subordinate bands of laminated sandstone grading into light blue sandy clay also occur and in both sections, on the road and railway, there is a clay band, 35 feet thick, near the base of the zone. Although this zone contains no coal, there are traces of carbonaceous markings and of fossil plants about $1\frac{1}{2}$ furlongs east of the anticline on the railway section.

**Coal-bearing zone.**

The predominating rock of the coal-bearing zone is a light, grey-blue clay often grading into shale. Associated with the coal seams is a plastic clay. The shales close to the seams are of a darker colour and pass into black carbonaceous shales or clays. Both the carbonaceous shales and the coal itself are universally crushed and slickensided.

**Age of the Coal Measures (the Loi-an series).**

The roof of the seams frequently contains traces of fossil plants in clay and from the Myinka area (mile 63-4) and Loi-an, Cotter has identified the following forms :—

*Cladophlebis denticulata*, Brong.
*Gingkoites digitata*, Brong.
*Pagiophyllum divaricatum* (Bunb.).
*Brachyphyllum expansum* (Sternb.).
*Ptilophyllum* sp. cf. *P. hislopi* (Oldh.).
*Podozamites distans* (Morris).

According to Cotter *Gingkoites digitata* is a cosmopolitan Jurassic species. *Pagiophyllum divaricatum* occurs in the lowermost Cretaceous group of Kachh. *Brachyphyllum expansum* (Feistmantel's *Pachyphyllum heterophyllum*), occurs in the Vemaveram beds (of Upper Lias to Lower Oolite age). *Ptilophyllum hislopi* is also found at Vemaveram, while *Podozamites distans* is found in the Lias at Rajmahal. The age of the coal is therefore taken to be Jurassic, but it is not yet possible to decide whether it is Lias or Oolite. The Coal Measures are now believed to be tucked in along axes of reversed folds in the limestones or faulted down into them, a view originally suggested by C. S. Middlemiss.

**Mesozoic coals of Yunnan.**

The nearest known Mesozoic coal-bearing rocks lie to the east in Central Yunnan and they too are overlain unconformably by a great thickness of Red Beds. The fossil fauna collected from the coal measures there by Coggin Brown has been ascribed to the Lower Noric or Upper Trias, that is to say they are somewhat older than these measures. The Napeng Beds which come between the Plateau Limestone and the Red Beds of the Northern States are unquestionably of Rhætic age, steeply dipping or vertical ;[1] small recumbent synclines and an anticline are known to occur in them.

**Supposed 'Bunter' beds.**

According to C. S. Fox, a series of hard sandstones and conglomerates quite distinct from the soft Red Beds of Kalaw occurs S. S. W. of Legaung, roughly east of the Thazi-Kalaw road about the 38th mile from Thazi, which underlie the Coal Measures of the Legaung ridge. We are well acquainted with the area in question and do not

[1] F. R. Cowper Reed, 'Palæozoic and Mesozoic Fossils from Yünnan', *Pal. Ind.*, Vol. X, Mem. No. 1, p. 203, (1927).

know of any conglomerates there other than those of the Red Beds, while the sandstones in question undoubtedly belong to the Coal Measures. We are therefore not in a position to accept a correlation of such beds with the Bunter, the lowest division of the Continental Trias of Germany, which Dr. Fox has tentatively proposed.[1]

## THE PLATEAU LIMESTONES.

Both sections of the Plateau Limestone occupy wide expanses in our area; the lower section, generally a white or light grey dolomite weathering to a darker colour, is always exceedingly brecciated and in cases where the secondary filling which cements it together has been leached out, is a soft shattered rock easily broken into fragments; the higher, a true limestone, is usually dark blue, grey or black in colour with a minutely crystalline texture. These latter rocks are tough and compact, break with a conchoidal fracture and are often fossiliferous. They usually occur as outlying masses, capping ridges and the crests of hills the main mass of which is built of the older variety.

**Inlier on the Legaung ridge.**

A narrow band of Plateau Limestone stretches from the north-western corner at the head of the Panlaung valley and crossing that stream continues south along the crest of the narrow divide known as the Legaung ridge between the Toklet and Taungwindwin *chaungs*, the outcrop being in some places less than a quarter of a mile wide, and at others pinched out for a short distance. It terminates in peak 4,452 near Lwè-lon (20°44′: 96°33′) in sheet 93 D/10.

**Inlier of the Sintaung ridge.**

Another similar band runs through the Coal Measures in the south-west corner of our area, building up the great craggy ridge with pinnacles and chimneys reaching over 6,000 feet in height and carrying the section of the railway line between Lebyin and Sintaung on the eastern side. This band is stronger and better individualised than that of the Legaung ridge and its northerly continuation crosses the Thazi-Kalaw road near Pyinyaung where it was first described by Middlemiss.

These occurrences are separated from the main expanse of limestone by the Mesozoic basin which occupies the eastern portion of the

[1] C. S. Fox, 'Occurrence of Cretaceous Cephalopods in the Red Beds of Kalaw', *Rec. Geol. Surv. Ind.*, LXII, p. 185, (1930).

sheets in the valleys of the Panlaung and its tributaries, and in the Kalaw neighbourhood. Except for the area occupied by the Pindaya inlier of Ordovician age or for the portions covered by Plio-Pleistocene and Recent deposits, the rest of 93 D/9 to the western borders of the Mawsön highlands in the north and the boundary of the Heho plain in the south is occupied by the Plateau Limestone.

**The main expanse of Plateau Limestone.**

It forms the plateau country which has a general altitude of about 4,500 feet stretching north from Aungban, through Kyong Namhkom (20°51′: 99°41′) and Myinkyado and descends to elevations of approximately 3,000 feet over the lip of the plateau on the west. It underlies the greater part of the Poila State and continuing north into Pangtara (Pindaya) wraps here up on to the shoulders of the higher and older lands on the east and west. The range which separates the Thamakan and Heho valleys and further north attains a height of 5,070 feet midway between Poila and Kyawktap is also entirely composed of Plateau Limestone.

Continuing to the south in sheets 93 D/10 and 14 the Thamakan range is only about two miles across where it is traversed by the railway, but from Thamakan southwards it rapidly increases in width, and with the exception of strips of Jurassic rocks faulted and folded down into it occupies most of the area of these sheets in the far south.

Further east it covers practically the whole of the sheet 93 H/1 east of the longitude of Taunggyi with the exception of two small inliers of lower Palæozoics, one behind the Taunggyi Crag and the other at Hopōng, and a small outlier of the Coal Measures in the extreme north-eastern corner of the area.

No useful purpose would be served by describing detailed exposures of these rocks and only a few of the more important occurrences can be mentioned. The older section is often buried under thick accumulations of residual deposits and is then only to be seen where the rare streams have carved their way through them.

**The lower brecciated dolomites.**

The rocky eastern slopes of the Thamakan range overlooking the Heho plain give an excellent impression of one type of country to which the lower limestones give rise and the difference between that type and the one formed by the older rocks, east of the Heho

valley, is apparent from places on the main Kalaw-Taunggyi road, where both can be seen.

The rocky heights behind Poila and the cliffs which contain the sacred caves of Pindaya are also excellent examples of their kind, though the latter belong to the younger group.

The broken brecciated variety is well displayed in the wayside quarry at mile 4 between Kalaw and Aungban (for it is extensively used as a road dressing), one mile south of Kyong on the Aungban-Pindaya road, at the head of the ascent to Taunggyi from the Yawnghwe valley and near the 'View Point', a favourite resort of visitors to the Shan Federal capital, Taunggyi itself; the great limestone cliff which overshadows the civil station is built of the older rock.

Even from the railway carriage as the train slowly climbs up the escarpment from Heho abundant exposures of the lower Plateau Limestones may be observed by the interested traveller. White dolomites crop out at the bottom of the ascent, near mile 388·5, and there are plenty of exposures about mile 387. Grey, brecciated dolomites are seen in the valley of the stream flowing to the south-east around which the line circuits near this point. The rounded slopes of hill 4,568 display a few low cliffs of grey and stained yellowish brown rock, while dolomites are quarried for ballast near the summit. On the descent the country is rougher and rockier until the late Tertiary deposits of the Thamakan plain are reached about mile 384-5. Unusual varieties of the limestone occur in the vicinity of Lwe-kaw (20°43′ : 96°44′). About one mile from it to the south, limestone conglomerates are interbedded with ordinary brecciated dolomites and with a red, ferruginous, platy limestone. In the railway cuttings the prevailing dip is low to the west, on the Thamakan side of Lwe-kaw, but steeper and in the same direction half a mile or so to the east on the other side. Here calcareous shales, slabby dark coloured limestones and yellowish-brown shales are interbedded with the dolomites. Lithologically, these are identical with certain types of the Permo-Carboniferous limestones but no fossils have been found in them. The red rocks to the east of Lwe-kaw are believed to be local modifications of the Plateau Limestone and not members of an older group as was previously believed.

The eastern boundary of the Plateau Limestones of the Thamakan range—a boundary where it is seen in contact with Silurian rocks, trikes N. N. W.–S. S. E. across the high country at the southern

end of the Heho plain, behind the peaks 4,937, 5,416 (Mebya Taung) and 4,868. Here as elsewhere the boundary rock belongs to the upper division and is very fossiliferous. Its dip is to the W. S. W. at 30°-40° and it thus appears to dip under the older brecciated limestone.

In sheet H/1 to the east, the country is more dissected and stands at a higher general level and contains an unusually high number of enclosed valleys, disappearing streams and sink-holes. About the longitude of Taunggyi the beds show an easterly dip, but further east the dips are in the opposite direction.

**The fossiliferous Upper Plateau Limestones.**

Localities in which fossiliferous Plateau Limestones occur are more frequent in the Southern Shan States than in the Northern ones where indeed they are rare, but La Touche's opinion that when the Southern Shan States came to be geologically surveyed, it would be possible to map the fossiliferous limestones as a separate formation, is still not fulfilled. The conditions at Lwe-kaw just described furnish one example of the difficulty facing any such attempt and after a considerable experience of the limestones of the Southern States, extending indeed far beyond the area under discussion, we have reluctantly to conclude that any such subdivision is at present impossible, for those very reasons which La Touche enumerates in the Northern States.

At the same time there can be no question that the upper fossiliferous limestones tend to occur near the 'islands' of older rocks. They are also often found as isolated hills and knolls which appear to us to be more of the nature of true inliers rather than patches of younger rocks lying as outliers on the older, brecciated material. These occurrences, particularly in cases where the fossiliferous 'upper' varieties appear at first sight to dip below the lower ones, have raised doubts in our minds as to whether the orthodox division into the two sections which we have followed consistently in this report is universally true, or to put the matter into other words whether it is correct to assume a Devonian age for the brecciated limestones over the hundreds of square miles which they cover, on the strength of two small isolated occurrences of Devonian faunas in the Northern States. La Touche himself found limestones with *Fusulina elongata* passing laterally and vertically into crystalline limestones indistinguishable from the usual type.[1]

[1] La Touche, *loc. cit.*, p. 256.

In another place he described Plateau Limestone as appearing to dip conformably below the red Jurassic sandstones.[1] Shales containing *Estheria* somewhat resembling *E. mangiliensis*, from the Panchet Beds (Lower Trias) of the Indian Gondwanas are inter-bedded with Plateau Limestone near Kyaukme in Hsipaw State.[2] A new fauna discovered in 1931 by Dr. M. R. Sahni at Na Hkam in North Hsenwi, consisting largely of ammonites and gastropods from argillaceous limestones and shale, interbedded with the 'older' dolomites, while including various upper Productus Limestone forms, contains, in addition, genera which have hitherto been recorded only from the Otoceras Beds (Lower Trias).

The possibility therefore that some of the so-called older brecciated dolomites are of Permo-Carboniferous or even of Lower Mesozoic age—and in the latter case later in time than the ones which have hitherto been described as 'younger'—is suggested. In this connection the recent descriptions of Upper Triassic fossils from the Taungyin limestones on the Burma-Siam frontier of Amherst district by Prof. J. W. Gregory is of more than passing interest.[3]

Amongst the more important fossil bearing localities are the following :—

(*a*) About one mile S. S. W. of Pindaya.
(*b*) Two miles north-east of Kyauk-su.
(*c*) One and a half miles south-east of Alèchaung (21 0′: 96°33′).
(*d*) Just to the south of Pon village, on the isolated, spindle-shaped outlier which exists in this neighbourhood.
(*e*) On the small hill, two miles W. N. W. of Pan-kan.
(*f*) Just north-west of Nyaungkaya (20°54′: 96°44′).
(*g*) Peak 4,546 feet, near Ohmin-bauk (20°38′: 96°46′30″) and further north-west.
(*h*) Peak 5,010 feet, four miles north of Hopōng.

Outcrops *a*, *c* and *d* have the characters of coral reefs and often contain great masses of reef-building organisms. *Fusulina* limestones occur near Pindaya and at (*e*) and (*g*). Brachiopods are common at (*e*) while (*f*) has yielded Clysiophyllid corals and the first specimens of *Lyttonia* sp. from the Indian Empire, outside the Salt Range.

[1] La Touche, *loc. cit.*, p. 257.
[2] La Touche, *ibid.*, p. 255.
[3] J. W. Gregory, 'Upper Triassic Fossils from the Burmo-Siamese Frontier', *Rec, Geol. Surv. Ind.*, LXIII, pp. 155-166, (1930).

At (*h*) concretionary, tabular fossiliferous limestone intercalated with partings of shale and dipping W. N. W. at 10° to 15° forms the crest of the hill-mass culminating in the twin peaks 4,475 and 5,010 feet, placed like a cake on top of sheared limestones and shales of Upper Ordovician age dipping to the east at almost 70°. The older dolomitised limestone was either completely removed by denudation before these Permo-Carboniferous limestones were deposited, or perhaps they were never deposited here. The assemblage is unusually rich, containing several Permo-Carboniferous forms of brachiopods and bryozoa, but the nature of the limestone renders them difficult of extraction even on roasting. A remarkable feature of the fauna is the discovery of a unique portion of an ammonite ? in it.

Large collections have been made from these and other localities which will certainly extend considerably our knowledge of these faunas and may indeed prove that other horizons than the one corresponding to the Middle Productus Limestone of the Salt Range exist in this region.[1]

## THE LOWER PALAEOZOIC SUCCESSION OF THE PINDAYA INLIER.

### The Wabya Graptolite Bed.

On the southern and western rims of the Pindaya inlier and between the Ordovician rocks and the unconformable Permo-Carboniferous limestones above, there occurs a band of black carbonaceous shale and slates containing a rich graptolite fauna. It was first found by Sondhi on the steep hillside half a mile east of Ngot-to-yagyi (20°54′: 96°36′) village and the outcrop continues to the top of the hill. A good section is also exposed on the footpath along the stream-bed just north-east of the village. From this point it has been traced about two miles north in a continuous band of varying width. Further north still, towards the edge of the sheet, it is probably represented by certain crushed and splintery slates. To the south the band can be traced continuously along the junction of the Pindaya beds as far as Wabya Taung (20°53′: 96°38′), the average width of the exposure being about one furlong, but further east and along the south-eastern limits of the Pindaya anticline it has not been found and is perhaps overlapped by the Permo-Carboniferous.

[1] C. Diener, 'The Anthracolithic Fossils of the Northern Shan States', *Pal. Ind. N. S.*, Vol. III, Mem. No. 4, (1911).

Wabya Taung itself is composed of light-coloured, soft shales, overlying the black ones which in turn rest upon yellow mudstones of Ordovician age. The former too are richly fossiliferous and although some of the graptolites are common to both groups, a preliminary examination leads to the conclusion that the Wabya fauna is the younger of the two, as indeed its stratigraphical position seems to indicate.

Associated with the graptolite shales is a band of light quartzitic sandstone sometimes weathering to fine sand. First seen to the south and west of Wabya Taung (5,419 feet), it persists, with the exception of a few gaps, to the northern edge of the sheet. Generally of a white colour, it is often iron-stained, and east of Alè-chaung is capped with boulders of laterite.

**Age of Wabya beds.** The following graptolites have been determined by Miss Elles in specimens from Ngot-toyagyi :—

* *Monograptus cyphus*, Lapw.
,, *incommodus*, Tqt.
,, *sandersoni*, Lapw.
* *Orthograptus vesiculosus*, Nich.
* *Climacograptus medius*, Tqt.
* ,, *prectangularis*, His.
*Glyptograptus tamariscus*, Nich., var. *incertus* (large form or new species).
*Mesograptus magnus* ?? (uncertain).

The species which we have marked with an asterisk are known to occur in the Pangsha-pye graptolite bed of the Northern States. The present assemblage like it therefore is attributed to the *Monograptus cyphus* zone of the Lower Valentian. It remains to add that *Orthograptus* is the most prolific genus locally, that *Climacograptus* is quite common, while *Monograptus* is comparatively scarce. Species belonging to the higher zone of *Monograptus sedgwicki* found by us at Panghkawkwo, near Loilem, have not yet been recognised in the Kalaw-Taunggyi region.

## The Pindaya Beds.

The Pindaya beds build the central and greater portion of the high range which is the watershed between the Zawgyi *chaung* and the Panlaung river; commencing in the high country to the

west of Poila, at an elevation of about 4,500 feet and striking due north, the range attains a maximum height of 6,474 feet above sea-level in Mené-taung, before it leaves the northern edge of sheet 93 D/9.

After crossing the steep frontal scarp of Permo-Carboniferous limestone which overlooks the Pindaya plain on the west, the calcareous shales, mudstones and argillaceous limestone bands which make up the Pindaya Beds are encountered. A typical series of exposures occurs on the track between Pindaya and Myinkyado. Near Twet-ni (20°56′: 96°39′) purple shales and light coloured calcareous shales crop out. Beyond them as far as the top of the range limestones predominate. The commonest variety is a massive, bluish grey, calcite-veined rock, generally bearing patches and seams of argillaceous material and often containing greatly contorted marly bands usually of bluish shades, more rarely pink and purple.

These rocks form the characteristic light brown soils of the higher parts of the range and have given rise to the intricate system of small cauldron valleys which scar its surface everywhere. Below the crest on the eastern flank the dip is E. S. E. at about 55°, but beyond it the direction changes and south-west or W. S. W. dips occur on the descent. The top of the range is thus the apex of an anticlinal fold, though this is itself corrugated by markedly acute minor structures.

In the southern parts of the range about Poila and Ye-o-sin, shaly horizons are commoner than they are further north.

The eastern boundary of the Pindaya Beds enters sheet 93 D/9, near Nyaung-le-bin (21°0′: 96°40′) and strikes approximately south for eight miles to the vicinity of Ye-o-sin (20°53′: 96°40′). Here it turns to the south-west and west and following the dry valleys north of Shanywa and Kyo-kyet crosses the southern spurs of Wabya Taung (5,419 feet) where it swings round to the north-west. Continuing in this direction for six miles it passes between Taungmyingyi (6,151 feet) and peak 5,625 feet on the west of it and then turns north, to follow an irregular line for four miles to the edge of the sheet near Alè-chaung. The greatest breadth of the exposure is in the north where it is about six miles from east to west.

Rhyolites are interbedded with the limestones and shales, at a point six miles north of Ngot-to-yagyi and also to the S. S. E.

of Menè-taung, 6,474 feet. They are very light coloured rocks with reddish-brown and orange spots, produced by the decomposition of pyrite, and hexagonal outlines of small quartz crystals. Always very decomposed they only occasionally exhibit a banded flow structure.

**Interbedded volcanic rocks of the Pindaya beds.**

Badly preserved and unidentifiable fossils are sometimes visible on the weathered surfaces of the Pindaya limestones, particularly at the pagoda-crowned hill just east of Ngot-to-yagyi (20° 54′ : 96° 30′ 30″), but the only locality which has yielded specimens worth collecting lies on the ridge half to one mile west of Ye-o-sin. From a collection made here Dr. Cowper Reed has identified the following fauna[1] :—

**The Naungkangyi (Ordovician) Fauna of the Pindaya Beds.**

*Orthis* cf. *irravadica*, Reed.
,, (*Nicolella ?*) *praetor*, Reed.
,, (*Dinorthis ?*) sp.
,, (*Glyptorthis*) cf. *lamellosa*, Twenh.
*Ptychoglyptus shanensis*, sp. nov.
*Yeosinella consignata*, gen. et sp. nov.
*Leptelloidea yeosinensis*, sp. nov.
*Sowerbyella ?* aff. *youngiana* (Dav.).
,, *?* cf. *ledetensis* (Reed).
*Christiania* cf. *tenuicincta*, McCoy.
*Petroria* cf. *rugosa*, Wilson.
*Camarella* sp.
*Protocrisina* cf. *ulrichi*, Bassler.
*Rhinidictya* cf. *nitidula* (Billings).
,, cf. *mutabilis*, Ulrich.
*Pachydictya* sp.
*Ptilodictya* sp.
*Favosites ?* sp.
*Batostoma* sp.
*Caryocrinus* cf. *turbo*, Bather.
,, sp. a.
,, sp. b.
Crinoid stem joints.

[1] F. R. Cowper Reed, 'Notes on some Lower Palæozoic Fossils from the Southern Shan States', *Rec. Geol. Surv. Ind.*, LXVI, p. 191, (1933).

*Illaenus* sp.
*Primitia* sp.
*Dictyonema ?* sp.

From the affinities of the new species in this list and of those which are comparable or identical with established species from definite horizons elsewhere, Dr. Cowper Reed concludes that this fauna is of Upper Ordovician age. This is also strongly suggested by the position of the Pindaya beds of Ye-o-sin, which appear to pass into the overlying Ngot-to-yagyi beds of Lower Silurian age without any stratigraphic break of consequence. At the same time, as Dr. Cowper Reed remarks, the Ye-o-sin fauna is different from that of Bawzaing and contains very few species which can be identified with those from the Lower or Upper Naungkangyi or the Hwe-Mawng beds of the Northern States or the Ordovician of Yünnan.

**Outliers of the Pindaya beds near Kyauk-su and Hopong.**

A small isolated occurrence of the Pindaya beds forms a low hill lying between a narrow lake in the Pindaya plain and the main Pindaya-Lawksawk road, one mile north of Kyauk-su (20° 58′ : 96° 41′30″). Here sheared and contorted calcareous shales dip south-west at from 45° to 50°, being replaced higher up by well-laminated blue shales dipping south-east at 52°. On the top are interbedded, light brown limestone bands while, on the north-western slope, chocolate and yellow mudstones dip north-west at 35°.

Another inlier of the Pindaya beds crops out at the head of the Hopong valley. The motor road from Taunggyi just touches its southern spurs before it is lost under the alluvium. Here too it is composed of the usual highly sheared limestone and purple and orange mudstone. The outcrop continues to the north for about four miles where it is split in two and is finally overlapped by Permo-Carboniferous limestone.

## THE LOWER PALAEOZOIC SUCCESSION OF THE MAWSÖN-MAWNANG REGION.

### The Kyawktap Graptolite Bed.

Near the junction of the Permo-Carboniferous limestones and the Orthoceras Beds just to the east of Kyawktap, Sondhi found bleached shales containing *Monograptus fimbriatus*, Nich. This

according to Miss Elles, who made the determination, is a Valentian form.

The exposure is a small one and quite liable to be missed. It is on the footpath leading down the eastern slope of the hill on which the Kyawktap pagoda—a prominent local landmark—is built.

Two small hills of little elevation rise from the alluvium of the northern end of the Heho plain south of Taung Bat (20° 48′ : 96° 46′).

**The Taung Bat graptolite beds and its probable continuation.**

In the southernmost of these there are poor exposures of white and buff papery shales from which specimens of *Orthograptus* sp. were obtained, but they do not occur in any abundance. This occurrence is four miles to the south of the one just described, as the crow flies.

The section to the east of the hill is obscured by alluvium but a little further on, at mile 7-2 from Heho, at the foot of the eastern boundary ridge of the valley, the underlying rocks are exposed as yellow purple and bleached buff mudstones containing broken cystidean plates and other fragmentary fossil remains. They have a high dip to the west and are underlaid in their turn, further up the slope, by slabby limestones containing *Orthoceras* sp., and sections of large, flat, coiled gastropods. These give place to more massive limestones of the Mawsön series described below. We correlate tentatively the Kyawktap and the Taung Bat graptolite-bearing horizons as Valentian.

## The Graptolite Beds of Mebyataung.

Mebyataung, 5,416 feet (20° 36′ : 96° 47′ 30″), is a prominent landmark rising steeply from the alluvium of the southern end of the Heho plain. In this region the Thamakan and Heho ranges meet and the Plateau Limestones of the former overlap on to the older Palæozoic rocks of the latter. Excellent sections of the strata near the contact are exposed along the footpath which leads south from the plain, passing Paw-lamaw and Wagyi-myaung to Taungbo-hla and Ngot (20° 33′ : 96° 47′ 30″).

The fossiliferous Plateau Limestone overlies unconformably various horizons of the lower rock groups, although both dip in the same direction.

**Overlapped contacts of the Plateau Limestone with the older series.**

Thus, to the east of Nat-daw, a soft sandstone underlies the limestone; north-east of Taungbo-hla, pink to brown phacoidal limestone forms the underlying bed; in the defile east of Ngot, an olive, platy, phacoidal limestone is exposed; south-east

of Taung-ni (20° 34′ : 96°49′) where the dips in both series are due south, Sondhi discovered a mauve mudstone containing *Tentaculites elegans*, Barr., and indeterminable graptolites, similar to the one occurring at another Taungni (south of Pon), except that in the latter no graptolites were found.

Associated with *Tentaculites elegans*, Barr., in the Taungni locality are, according to Dr. Cowper Reed, the following forms :—

*Styliolina clavulus*, Barr.
*Eutomis* cf. *phalanga*, Kegel.

These occurrences lead to the assumption that the Zebingyi beds are represented here.

The graptolite beds.

The best section of the Silurian and Ordovician rocks was found along the footpath between Paw-lamaw and Taungbo-hla. Here, commencing from the top of the series, pinkish-brown phacoidal limestones are prominent at the top of the hill. The phacoidal limestone ends at the foot of the hill where it overlies a slightly sandy and micaceous, unfossiliferous mudstone. Below this again is a bleached shale containing faint graptolite remains (Bed C).

It is followed by alternations of thin bands of shales and mudstones, in which no fossils were found, for about three furlongs from the boundary of the Plateau Limestone, where the second graptolite bed (Bed B) occurs. It is composed of pale bleached shales in which the graptolites occur in greater profusion and in better preservation than in the case of Bed C.

Some 40 feet below Bed B, the intervening ground being covered, there occurs the lowest graptolite horizon Bed A, the species of which recall those found at Ngot-to-yagyi and Wabya Taung. In the whole of the section in which the three graptolite beds occur there are only two thin beds of limestone.

The dip of Bed C is south-west at 35°. Along the strike this bed continues past Mebya Taung, its outcrop being easily discernible from the light soil to which it gives rise.

The graptolite shales are underlain by a brownish phacoidal limestone of small thickness while below this come various types of limestone of the Mawsön group, which we regard as of Upper Ordovician age. The uppermost limestone bands contain sections of fossils which cannot be extracted.

In the following table the various graptolite species from the three horizons, as determined by Miss Elles, are given. In her opinion Bed A is the lowest and Bed B the highest of the group:—

| Bed A. | Bed B. | Bed C. |
|---|---|---|
| *Monograptus gemmatus*, Barr. . | *Monograptus sedgwicki*, Portl. | *Monograptus tenuis*, Portl. |
| *Monograptus concinnus*, Lapw.. | *Monograptus tenuis*, Portl. | *Monograptus millepeda*, McCoy. |
| *Monograptus jaculum*, Lapw. . | *Climacograptus scalaris*, His. | *Climacograptus törnquisti*, Elles and Wood. |
| *Monograptus gregarius ?*, Lapw. | .... | *Climacograptus scalaris*. |
| *Climacograptus törnquisti*, Elles and Wood. | .... | .... |

## The Orthoceras Beds.

The Orthoceras Beds form the greater part of the western limb of the broad Mawsön anticline. They are generally hard, flaggy, brightly coloured, red, pink or purplish argillaceous limestones and calcareous shales with a highly developed phacoidal structure, which on weathering causes them to develop a characteristic pattern recalling that of crocodile hide. They usually contain large crinoid stems and numerous specimens of *Orthoceracones*.

They enter the northern part of the sheet 93 D/13 near Gwe-kot (21°0′ : 96°45′) and sweep in a curved band, about two miles broad, to the south between the Gwebin-Thit-è-bin plain on the west and the Mawsön highlands on the east for some six miles. Here they curve around and edge the The-gon–Kyawktap valley on the east again striking south, thinning in width of outcrop and finally disappearing below the Sub-Recent deposits of the Heho plain. At the northern end of the sheet a band of these rocks averaging about a mile in width, borders the northern end of the Gwe-bin plain for about three miles.

Between Hgnet-thauk (20°58′ : 96°42′) and Ye-u the junction between these beds and the Plateau Limestones is crossed, and under the latter lie pale blue shales and hard buff mudstones interbedded with thin bands of crocodile-hide patterned pinkish-brown limestone containing *Orthoceracones*. The dips are to the W. N. W. near the junction, but soon change to the E. S. E. or south-east at about

50° ; near Ye-u however, the dip is westerly again, in pinkish white, sheared limestones.

Crossing from the westerly dipping Plateau Limestone in the Kyaukse valley towards Myin-kyaw (20°57'30" : 96°42'30") sections are poor, but shales and mudstones are again found with interbedded limestones of the normal type. Highly inclined dips to the north-west exist here but resume a south-easterly direction further east.

The most typical examples of the Orthoceras Beds are found in the valley to the east of Paw-myin (20°58' : 96°45') and again, on the flanks of peak 4,613, to the northeast of Nyaung-kaya. In the former locality they contain bands of sandy, yellow mudstones with badly preserved fossils recalling those of the Naungkangyis. Like the phacoidal limestones the calcareous shales also contain bent and fractured specimens of generally indeterminate *Orthoceracones*, the only genus so far recognised being *Actinoceras* sp.

*Age of the Orthoceras Beds.*

The extended time range of *Orthoceras* and its cosmopolitan character are of no assistance in identifying the exact age of these beds, but if we are correct in assuming a Lower Silurian age for the graptolite beds of Kyawktap and Taung-bat it appears possible that the Orthoceras Beds belong to that age.

Lithologically they have much in common with the Nyaungbaw limestones of the outer platform of the Northern Shan plateau and like them they appear to be of extremely restricted distribution, for although we have traversed the Southern Shan States east of Taunggyi into Kēngtūng and the Salween valley, we have found no other rock group which closely resembles them. On the other hand the Orthoceras Beds as far as we know do not contain *Camarocrinus asiaticus* which is characteristic of the Nyaungbaw limestone and has been found by Coggin Brown further east still in Yünnan. The attribution of an Ordovician age to this species in Burma has caused some controversy as it belongs to much higher horizons in Bohemia and America, but the discovery of Ordovician brachiopoda and bryozoa in outlying patches of beds associated with the Nyaung-baw limestones in the hills north of Maymyo, seems to have silenced the criticism. Limestones, resembling the Nyaungbaws very closely, occur in the Hwe-Mawng beds of the eastern ranges of the Northern States, indeed, in south Hsenwi, identical rocks are found at the top

Possible correlation with the Nyaungbaw limestones.

of the Hwe-Mawngs which are themselves of Upper Naungkangyi age. Finally the limited fauna of the Mawsön beds, as we shall show later, indicates an Upper Naungkangyi correlation and again, if we are correct in assuming that the Orthoceras Beds overlie them, it follows that they cannot be any older and they may be Silurian. This view is advanced with much diffidence, for the structure of this particular area is by no means clear and demands more detailed mapping than is possible on the only available one inch to one mile map, while comparisons on lithological grounds we know from experience are of little value.

It may be recalled here for the benefit of the reader unfamiliar with Shan geology that the affinities of the Upper Naungkangyis are with Stage C of Schmidt's classification of the Ordovician rocks of the Baltic Republics and that no representatives of the higher Ordovician —the Ashgillian types—have as yet been proved to occur.

## The Mawsön Series.

The Mawsön series forms the eastern part of the Mawsön highlands and although the character of the country does not permit the mapping of an exact boundary line between this series and the Orthoceras Beds, various differences exist which make it necessary to attempt their separation. The phacoidal limestones and calcareous shales overlying the mudstones and sandy shales of the latter group give rise to their own indefinite type of topography very different from that of the east, where thick limestone horizons separated by a few strongly developed beds of sediments persist across country in a fashion that the others do not follow. Eastern Mawsön is a region of great limestone escarpments and big valleys of enclosed drainage, and it is from such differences—the only possible method under the circumstances—that the placing of a sketchy boundary line has been attempted.

**Exposures about Mawsön.**

Approaching Mawsön itself by the footpath across the detour made by the motor road from Heho (20°43′ : 96°49′) the shaly bands of the Orthoceras Beds further west become thicker, more prominent and lose their red colour, though they still contain much argillaceous material. At the crest of the last ascent there are a few exposures of the western type, but distinctly approaching the lithological character of the new varieties found further east. The nearest

hills contain these; their slopes are rocky and there is only a patchy covering of thin red soil upon them for they are too stony and barren for general cultivation. Hereabouts the country becomes almost entirely calcareous with the exception of the zones occupied by subordinate sedimentary bands. Instead of the worn grassy or cultivated gentle slopes of the west, we now find massive limestone scarps with rough screes below them and all the other features of typical *karst* landscapes. East of Mawsòn, where the higher elevations of this limestone area exist and culminate in the peak 5,473 on the borders of Lawksawk State, the country is exceedingly rough and difficult to traverse. Once the few existing footpaths which usually coincide with the crests of the ridges are left, the traveller is compelled to climb steep scarps and descend into precipitous sink-holes in monotonous succession, his progress impeded and observations made difficult by thick growths of giant grasses in the sheltered situations.

**The sedimentary bands of Bawzaing.**

A common type of limestone is a homogeneous, light bluish grey or brown, compact, finely crystalline rock. Within the leased area of the Bawzaing Mines (20°57' : 96°48') there are three sedimentary bands running approximately from north to south and dipping in an easterly direction. They pass insensibly into the limestones above and below them while in the valleys and on the lower slopes their outcrops are usually masked by scree or residual deposits. In most cases their presence is only indicated by small fragments of brown sandy shale or reddish sandstone, the altered surface representatives of the harder, more massive rocks below.

**The sandy sediments pass imperceptibly into limestones.**

In connection with a study of the lead-ore deposits of Bawzaing the rocks hereabouts were closely examined and examples of the gradual transition of limestone into sediment observed. Approaching the latter the limestone bands become thinner and the bluish grey rock develops tiny grains of a brown impurity, still in a semi-crystalline, bluish matrix. These then segregate into patches and irregular veinlets, while secondary calcite makes its appearance in films and veinlets. The brown impurities collect together more and more, and then form irregular, contorted or wavy layers in the bedding planes, sometimes ending in a lenticular fashion, but often traceable for greater distances. Simultaneously the mosaic of the groundmass parts with its crystalline character and becomes dull, porcell-

anous or earthy. Ferruginous layers, reddish purple, red and reddish brown appear, and eventually, dirty, yellowish brown marls with bluer, more calcareous patches develop, alternating with fine-grained, calcareous sandstones, silt and mudstones—representatives of the sedimentary horizons. The only fossil actually obtained from the limestone at Bawzaing itself is a large specimen of *Cyractinoceras* sp.

It is not uncommon in the Shan States to find soft marls and sandy mudstones as the weathered products *in situ* of limestones, which in their fresh condition show little evidence of the large amount of earthy matter they really contain. At Bawzaing the irregularly banded bluish, argillaceous limestones can be traced passing directly into yellowish-brown marls. Cuttings through the limestones also expose thin interbedded layers of ochreous shale. The weathered rocks show a well developed cleavage, typically crossing the easterly dip at about 70°, which is not visible on the unaltered rock.

The Mawsön series in the latitude of Mawsön itself is exposed over a breadth of seven miles and similar or closely related rocks are believed to continue to the south forming the range which separates the Heho valley from the Inle one in sheets 93 D/13 and 14. In this direction it narrows, being some 4½ miles across at Hethintaung, 5,133 feet, its highest point in this portion. At Heho where it is crossed by both the main road and the railway it is only two miles broad.

**Exposures on Hethintaung.**

North of Hethintaung (20°47′ : 96°50′) its surface is everywhere marked by cauldron valleys and disappearing stream beds, but further south most of the drainage appears to find its way into one or other of the valleys on either side. This is partially a result of its compressed width in this direction, but probably mainly to be accounted for by the greater predominance of impervious shaly layers to the south. Thus, in the ascent of Hethintaung from Kya-hon-daung (20°46′ : 96°48′) while typical limestones occur in the isolated 4,178 hill surrounded by alluvium to the west of the village, practically no limestone is seen on the main ridge as far as the top of the mountain.

**Exposures in the railway cuttings.**

The rocks of the railway cuttings over the Heho ridge show various alternations of limestones, mudstones and slaty shales. Middlemiss noticed how the limestone differed from his Thamakan limestone, which we now know to belong to the Plateau group.

'It is rather darker', he wrote, 'than the Thamakan limestone, of a blue-grey tint within, but weathering greenish grey to a considerable depth. It is as a whole rather inclined to be well bedded, as can be seen in the road sections, is sometimes semi-concretionary and but very seldom brecciated to any extent. It is interbanded with pale shaly and marly layers. A noticeable feature in the limestone is that it possesses thin interbandings of ferruginous layers ½ inch wide which stand out from the greenish grey limestone in marked ragged relief. In some cases as near Heho these ferruginous layers may be seen to consist of compacted shelly layers. There is just enough evidence to show that some form of molluscan life had there been present, but no more. None of the shells could be isolated or identified even genetically.'

Fossiliferous band in the railway section.

After much search we have found a thin fossiliferous band of sandy shale near bridge 378—a band which is much sandier than the light coloured calcareous shales dipping east at 46° around it. About mile 396-16 on the railway line a single cystid plate was collected from soft mudstones, resembling a Naungkangyi variety very strongly, while the slaty limestones which lie between them and the disturbed slates of the cutting near Nam-noi viaduct, appear to be entirely unfossiliferous. Sections of *Orthoceracones* have, however, been found in other limestone bands nearer Heho, but they are of very rare occurrence.

In the sections between Nam-noi and the alluvium of the Inle plain, after leaving the slates exposed near the viaduct, there are many repetitions of the impure argillaceous limestones of the Bawzaing types, bluish-grey rocks with patches and films of brown and red colours. Their general dip is towards the east but near mile 398-2 there is another zone of intense disturbance with much shattering, shearing, folding and crumpling together with the impregnation of thin quartz and calcite veinlets. Beyond this zone the limestones again assume their eastern dip.

## *Age of the Mawsōn series.*

Fossils from Bawzaing.

From a sandy silt-stone exposed in a cutting on the Bawzaing-Baw-lon (20°54′ : 96°48′) road, near Twin-su, one mile south of Bawzaing, fossils were obtained which were identified by Dr. Cowper Reed as follows:—

*Orthis (Dalmanella) emancipata*, sp. nov.
*Lophospira* cf. *alternans*, Koken.
" cf. *elevata*, Ulr. and Scof.

*Lesueurilla* cf. *infundibulum*, Koken.
*Helicotoma* cf. *tamurai*, Kob.
,, cf. *planulatoides*, Ulr.
*Liospira* ? sp.
*Cyrtolites* cf. *nodosus*, Salt.
*Hyolithes* sp.
*Orthoceras* (*Spyroceras*) sp.
,, (*Cycloceras* ?) sp.
*Ogygites* cf. *yunnanensis*, Reed.
Crinoid stems.

From a sedimentary band at the top of Siderite Hill, the southernmost of the two peaks which overlook the enclosed Bawzaing valley on the west, come the following:—

*Orthis* (*Dalmanella*) *emancipata*, sp. nov.
,, *praetor*, Reed.
,, cf. *vespertilio*, Low.
*Pliomera* sp.

Detailed descriptions of most of these fossils with notes on their affinities have been published recently by Dr. Cowper Reed.[1] They indicate a new type of the Shan Ordovician fauna, most of the species having been previously undiscovered. On the whole they suggest an Upper Ordovician age.

From half a furlong west of bridge 378 between Heho and Nam-noi on the railway, Dr. Cowper Reed has identified the following forms:—

*Orthis* (*Dalmanella*) *mansuyi*, Reed.
,, *hehoensis*, sp. nov.
*Proetus* sp.
*Cyphaspis* cf. *convexa*, Corda.
*Bathyurus shanensis*, sp. nov.
*Phacops* (*Dalmanites*) sp.

*Orthis mansuyi* is a form allied to the common European *Orthis elegantula* and has already been described from the Pangsha-pyè beds. *Cyphaspis convexa* has been found in Tonkin in Silurian beds associated with *Phacops longicaudatus* var. *orientalis*. The latter occurs in the Upper Namshim stage of the Northern States. The nearest earlier occurrence of *Bathyurus* to the present one is from the

[1] *Rec. Geol. Surv. Ind.*, LXVI, pp. 181-190, (1933).

Lower Ordovician, Pupias beds of Yünnan where *Bathyurus mansuyi*, Reed, was collected by one of us some years ago.

Dr. Cowper Reed regards these Heho beds as Silurian. On stratigraphical grounds we are inclined to place them in the Upper Ordovician. The question is likely to remain debatable until a more extensive fauna has been found in them.

### LOWER PALAEOZOIC SUCCESSION OF THE PON-TAUNGGYI REGION.

At its northern end the Yawnghwe plain is separated from the Kun-lon plain by a narrow strip of elevated ground which runs from the foot of the Mawsön highlands near Sinchaung (20°53′ : 96° 51′30″) east through Pon (20°54′ : 96°56′) where it joins a short ridge. This reaches a height of 3,945 feet and continues south for three miles before it terminates near Salē (20°47′ : 96°58′) against the high-level terrace of the eastern border of the Yawnghwe plain. Between the end of this short ridge and the terrace is the narrow gap made by the Pangwe *chaung* (on its way south to join the waters of Inle Lake), which has been dammed near Kônleau (20°48′ : 96°59′) and forms the irrigation reservoir known as the White Crow Lake.

The narrow strip of elevated ground first mentioned is breached by the Namlap in a deep narrow valley, to the west of which lie old elevated lake deposits pierced by three islands of rocks belonging to the Mawsön series while to the east are situated other older Palæozoic rocks to be described. They too bear in places remnants of old lacustrine deposits seen in places as clayey layers under the soil capping and now undergoing slow lateritisation.

**The Plateau Limestone band near Pon.**

East of the Namlap the Lower Palæozoic succession is interrupted by a narrow band of Plateau Limestone, extending through Pon, right across the ridge from north to south. Although mainly made of the older brecciated dolomite, there is one patch half a mile south of Pon where crinoid stems, bryozoa, including *Fenestella* sp., and corals indicate the presence of the younger division.

## Upper Silurian Rocks around Pon.

East of the Namlap *chaung*, forming the greater part of the patch east of Pon and rising to a height of 3,500 feet, is a series of dark grey limestones, often containing *Orthoceras*, of pale pink,

phacoidal limestones and of reddish brown sandstones and shales. The latter are fossiliferous and are best seen on the north-eastern slopes of point 3,384 feet. Peak 3,500 feet, south of Pon, is composed of hard, dark grey sheared limestone, while in the end of the ridge west of Pan-taw (21° 0′ : 96° 57′) pale grey limestones blotched with brown occur.

From the shales Sondhi has obtained many fragments of trilobites and one practically complete specimen. Unfortunately these remains are in a most delicate condition, though every detail of the structure is preserved.

The complete trilobite appears to us to belong to the genus *Phacops sens. str.* as the glabella is unfurrowed and inflated. In its thoracic segments and small rounded pygidium the specimen shows resemblances to *Phacops latifrons.* Now, although several members of the family *Phacopidae* have been described from the Shan States, they all with one exception belong to the sub-families of the *Dalmanitinae* or *Pterygometopinae.* This exception is *Phacops* (*Phacops sens. str.*) *shanensis*, Reed, from the Zebingyi beds. Only imperfect casts in a poor state of preservation are known but there are resemblances to our specimen. (Since this was written the specimen has been determined as a new species and named *Phacops ponensis* by Dr. Cowper Reed.)

On the analogy of *Phacops shanensis* we were inclined to the belief that in this neighbourhood we were dealing with beds of Upper Silurian age, a conclusion which we believe to be confirmed by Sondhi's discovery of *Tentaculites elegans.*

**Shales and limestones with *Tentaculites*.**

East of the intervening Plateau Limestone band, the ridge to the south-east of Pon consists of a steady easterly dipping sequence. At the bottom, and rarely seen, are thin bands of pink phacoidal limestone interbedded with shales. Above them come dark grey limestones with *Orthoceras* sp. and crinoid stems and a few bands of a pinkish black, soft, sandy mudstone crowded with *Tentaculites elegans*, Barr. Higher still the grey limestones are interbedded with light dark grey quartzitic sandstones, weathering to a brown sandstone, which in their turn give place to interbands of hard bluish white shales. Peak 3,945 feet is composed of platy limestone and similar rocks. The north-east dip of its northern flank is probably due to local disturbance,

Our specimens of *Tentaculites* agree with Dr. Cowper Reed's descriptions of the Zebingyi forms.

'They are slender, conical shells, tapering at first rather slowly and then more rapidly towards the apex; the rings which annulate the shell are regular, equal and equidistant, and they are separated by rather wider interspaces.'

They too show the longitudinal groove or depression extending from the mouth down one side of the shell which is too common a feature to be the result of accidental injury. The average length is 3 to 4 mm., but some specimens reach 7 or 8 mm.

*Tentaculites elegans*, Barr., is a Devonian species, but for reasons given by La Touche it is classified in the Shan States with the Silurian, though it is evident that we are dealing here with strata of a transitional character.

**The Taung-ni-Okpoywa section.**

A road leads across the ridge from Taung-ni to Ôkpoywa (20° 50′ : 96° 59′). On the western lower slopes, tabular, grey and pink blotched limestones dip east at 25°. Above them lie tabular limestones interbedded with mauve and black shales similar to the ones containing *Tentaculites* further north, but in this locality no trace of fossils was found. These in their turn are overlain by dark grey limestones which prevail until the top of the pass is almost reached. Orange mudstones form the summit and continue down the other side for three furlongs, to be replaced by light-coloured sandy shales containing very badly preserved graptolites. These appear to be unidentifiable but the much greater abundance of diplograptid forms, compared with the monograptids, would seem to indicate an horizon considerably lower in the Silurian sequence than the one occupied by the *Tentaculites* beds. Above the stained and bleached graptolite bed there are brown sandy micaceous mudstones with no fossils. A long blank stretch follows with no outcrops. Towards Ôkpoywa pink and brown phacoidal limestones with a few grey bands are found. These are crushed and contorted and in no way comparable with the tabular bedded rocks of the western flank.

## Fossiliferous Naungkangyis behind the Taunggyi Crag and at the foot of the Taunggyi Scarp.

Behind the Taunggyi Crag there is a small inlier of Ordovician rocks, consisting mainly of argillaceous limestones weathering to olive sandy mudstones from which a few fossils have been obtained.

We believe we have here rediscovered the fossiliferous locality from which Sir Henry Hayden in 1911 sent a few poor specimens labelled 'from hill behind Taunggyi' to Dr. Cowper Reed.

These included the following:—

*Hyattidina* sp.
*Loxonema* sp.
*Phacops* sp.

From Sondhi's later collections he has provisionally identified the following forms:—

*Lindstroemia* sp.
*Protozyga sondhiana*, sp. nov.
*Sowerbyella innexa*, sp. nov.
*Chonetoidea* sp.
*Camerotoechia* ?? sp.
*Calymene* sp.

It is not at present clear from the affinities of these new species whether the forms belong to the Upper Ordovician or the Lower Silurian. From a stratigraphical point of view we are inclined to place it with the former.

Behind the first platform of high-level terrace deposits, the precipitous scarp of Taunggyi is composed of Ordovician rocks, overlain by Plateau Limestone. The Lower Palæozoics themselves consist mainly of limestones masked in the road sections by great masses of travertine, but fossiliferous mudstones also occur. Amongst the limestones the following types may be mentioned:—black with calcite veins simulating the Permo-Carboniferous types; highly sheared chocolate-red calcareous shales with nodules and rare crinoid stems; bedded grey limestones with argillaceous partings and pale buff or deep orange-red fossiliferous mudstones. From the latter, near the village of Taungtha-hla, on the footpath from Taunggyi to the foot of the hill, Dr. Cowper Reed has identified the following forms from a collection of fossils made at this vicinity:—

*Orthis laminata*, sp. nov.
,, (*Glyptorthis*) sp.
,, *chaungzonensis*, Reed.
,, sp.
*Skenidioides* cf. *aelandicus* (Wiman).
*Leptaena rhoboidalis* (Wilck.) var.
*Sowerbyella* sp.

## STRUCTURAL GEOLOGY.

**Structural affinities between the Shan uplands and the Himalayas.**

There is a broad structural parallel between the Shan uplands and that portion of Northern India usually known as the Extra-Peninsula area. To Middlemiss as he approached their western edge as it rises steeply from the plains, the hillsides, spurs and ravines conveyed convincing evidence of free sculpturing at the hand of time, while the towering sharp-edged ridges, the wide and deep gorges, and the flowing slopes between them reminded him of the older zones of the Lower Himalaya which he had just left. In the thin, acute-angled, irregular and vermiform summits, he perceived sub-aerial denudation accomplishing its work and the ridges being scored and fretted into all the forms so characteristic of a relatively old land area. Middlemiss suspected the existence of an outer boundary fault—a well-founded suspicion, which was proved true later—, and having reached the plateau itself he soon realised that he was not dealing with the normal undulations of vertically elevated blocks of strata; the straight boundaries between the various formations, the tendency to a universally orientated strike and its corollary—the arrangement of the various rock-groups in more or less straight bands—together with their sequence from west to east, suggested to his mind a comparison of the tableland with the Himalayas, both areas having suffered distinct sets of lateral compression at different times, accompanied in places by overthrusting.

While Middlemiss dealt mainly with surface-forms and morphological features, La Touche after his years of field-work carried the arguments further, on more purely geological grounds, so that to-day we are left in no doubt of the common features of the two regions. Thus, as La Touche writes[1]

'On the Burmese side we have the Shan plateau, corresponding, but at a much lower elevation, with the Tibetan plateau, both of them the elevated floors of an ancient ocean, now undergoing abrasion and reduction to a peneplain. The outer edge of each plateau is bounded by what is virtually a scarp; and though it may seem almost absurd to compare the mighty chains of the Himalaya with the insignificant fringe of Archæan and Palæozoic rocks that borders the Shan plateau, they certainly seem to bear some likeness to each other from a geological if not from a physical and spectacular point of view. Both are composed, speaking generally, of rocks older than those of the plateau beyond, and in both cases

[1] *Loc. cit.*, p. 356.

the main rivers, gathering on the uplands, break across the strike of the rocks through profound gorges. In each case the zone of older rocks is bounded by a great fault, or series of faults, forming the inner edge of the "foredeep" that separates them from the "foreland" of the continent beyond. In front of this again we have a zone of Tertiary strata, thrown into folds and greatly dislocated by faults, in the one case occupied by the Tertiary series of the Irrawaddy valley, and in the other by the Siwalik strata of the sub-Himalaya.......'

**The Shan folding slightly preceded the Himalayan.**

The Shan arc of folding was probably shortly precedent in time to the commencement of the manifestation of the forces which eventually raised the Himalayas. In both cases these forces are still in operation, a fact of which both Burma and the Shan States have been unpleasantly reminded by the recent revival of seismic activity, caused by the growth of faults associated with the outer boundary fault along a narrow zone lying at the foot of the hills.

**Comparison between the Northern and Southern Shan regions.**

Compared with the surveyed portion of the Northern Shan States lying to the east of Mandalay, we find in the sections between Thazi and Kalaw a wide belt of crystalline rocks forming the outer ranges before the Southern Shan highlands are reached. In the former case the crystalline rocks build the Sagaing hills and underlie the Irrawaddy plain about Mandalay.

The Pre-Cambrian Chaung-Magyi series and some of the older Palæozoic formations may be represented in the Southern area before the first exposures of the Plateau Limestone are encountered —but this outer fringe has still to be surveyed in detail. The most striking difference in the two areas is the occurrence in the south of a great Mesozoic basin, faulted down into the older rocks and forming the brow, as it were, of the highlands behind and extending over the brow on to them. In the Northern Shan States when the narrow outer fringe of older Palæozoic rocks has been crossed and the plateau itself reached, a long distance has to be traversed before the first Jurassic basin is met with south-west of Hsipaw. Another remarkable difference, at any rate in the latitudes we are dealing with, is the absence of exposures of the old Pre-Cambrian floor, piercing through the later formations, for it is not until the Salween valley is reached that the Chaung-Magyi rocks are exposed along the Thazi-Kēngtūng route.

Along the western edge of the Northern Shan plateau the axial direction of the folding is north and south, a direction which is

also followed in the main by the great sag faults which fracture the Plateau Limestone further east and again, by the Lilu overthrust in the Nàm-Tu valley. To the east of the Nàm-Tu, the Red Beds of the Jurassic Namyau series and the Plateau Limestone are both bent into regular folds striking from N. N. E. to S. S. W. In the eastern ranges of the Northern Shan States there is much diversity in the directions of the longer axes of the elongated domes in which the older rocks occur. In our area the trend of both major folding and faulting is north and south, for there are no exposures of the old rocks which formed the floor of the Palæozoic sea and which have locally affected the fold trends in the eastern ranges. Our area therefore corresponds in these particulars with the outer zone of the northern plateau and with the direction which the axes of folding are known to assume in Northern Siam.

**The direction of the fold-lines.**

It is exceedingly doubtful whether any traces of the original peneplain of late Cretaceous ? age exist anywhere in the Shan States, where denudation is so active and erosion so intense, and where the overwhelming preponderance of soluble calcareous rocks, exposed to the intensified attacks of a seasonal monsoon climate, assist the natural agencies of land decay and destruction to a very remarkable degree. The plains of the area with which we are concerned and indeed those that we know elsewhere in the States, whether of the upland type or of the generally lower variety formed in the various lake basins, must all be of comparatively young origin. Clearer evidence could not be forthcoming than that furnished by the Thamakan, Heho and Yawnghwe plains, that they were formed at different times and at different elevations far above the existing base-levels of erosion.

**The plains were formed at different times and at various elevations.**

The Thamakan lake, whatever its origin may have been, was doubtless enlarged by the growth of a great solution hollow in the Plateau Limestones which fringe the Mesozoic basin of Kalaw on the east and re-appear again in the Thamakan range, between these lake deposits and the Heho plain. This Plateau Limestone zone is folded into gentle, approximately north and south trending flexures. To Middlemiss the scattered scarps and low dip-slopes which fringe it east and west suggested a

**Folding of the Plateau Limestone.**

'billowy, broadly extended synclinal with a scarp possessing gentle dips to the west, at the descent into the Heho plain'.

Further north, the eastern section of this stretch of Plateau Limestone ends on the southern slopes of the Mawsön dome and we suspect the existence about here of a major monocline in the vicinity of Kyong, which further north still, breaks, and becomes an actual fault which forms the eastern scarp of the Pindaya range.

**Eastern fault scarp of the Pindaya ridge.**

The results of the compressive forces that have affected the Shan plateau may, as La Touche wrote, be placed under two distinct heads: (1) the production of more or less regular folds, accompanied by overthrust or reversed faults parallel to the strike of the folds, and (2), vertical faults due to the sagging down of the underlying Archæan floor under the influence of gravity. These latter faults bear no relation to the direction of the strike of the rocks, but follow straight or slightly curved lines for considerable distances and are often at right angles to each other, while they are frequently visible at the surface as long lines of vertical scarps.

**Compression has caused both folds and faults.**

Examples of the reversed or overthrust type of faulting almost certainly occur in the Mesozoic rocks, particularly in the Coal Measures, in which an example has already been described. Their presence is suspected in the Mawsön (Ordovician) series, both in Mawsön itself and in the Heho range in the latitude of the town of the same name.

**Overthrusting in the Mesozoic basin.**

The Heho basin may not be of direct tectonic origin, for, although it is flanked on the west by Plateau Limestone and on the east by older, Ordovician ones, the junction of two rock groups where they meet beyond its northern end appears to be normal and uncomplicated by faulting. Continuous exposures are however lacking in this area and more has to be left to the eye of faith than is desirable. We therefore leave the question of the origin of the Heho basin an open one for the time being.

**Origin of the Heho basin is doubtful.**

It is only reasonable to expect that the extraordinary system of parallel sag-faults, which lie between Maymyo and the edge of the Shan plateau east of Mandalay, which have stepped it into definite tiers and which have done so much to diversify its scenery, by

**Fault scarps of the Yawnghwe valley.**

the production of great limestone scarps running for many miles, should have some counterpart, if not direct continuation in the region under discussion. In the case of the Yawnghwe depression containing the Inle Lake it is hard to resist the conclusion that vertical block-faulting has been at work strictly comparable with that just described. The high double-storied wall, the upper portion of which is well set back from the lower, fringing the valley on the east, and the precipitous edge of the Mawsön highlands overlooking the plains of the Namlap—perhaps once occupied by an extension of Lake Inle—on the west, have all the appearances of fault scarps.

**The Mawsön dome.**

The Mawsön highlands have been referred to as a dome, as indeed when looked at as a whole they appear to be. It is doubtful however whether their structure is as simple as this and it may prove that the long succession of limestones visible on the east are repeated examples of the same group multiplied in closely packed overfolds or even overthrusted, for large scale work on a small area near Bawzaing indicates the presence of numerous sharp, minor but persistent corrugations, neither the stratigraphical differences of the rocks, the continuity of their exposures, nor the few fossiliferous horizons being sufficient to permit their distinction. The solution of this problem is likely to be found in the more southerly extensions of the Heho range.

**Sequence of major geological events.**

Our work has added no new knowledge to the pre-Plateau Limestone history of the region beyond that already known through La Touche's researches. In the Southern States as in the North the Plateau Limestone overlaps all the formations beneath it and there is the usual sharp differentiation between the brecciated section of this formation and the Permo-Carboniferous limestones. There is certainly an unconformity of great magnitude between the latter and the Jurassic beds, which appear to have been laid down in large independent basins on the limestone floor. Movements on an epeirogenic scale took place sometime in the Mesozoic and resulted in the severe crumpling of the Coal Measures before the Cretaceous Red Beds were unconformably deposited upon them. The evidence which we have tabulated in support of these observations constitutes an advance on our knowledge of the Mesozoic events as they are revealed in the Northern States. Finally the

whole area was involved in what are usually termed the Himalayan movement, though it was antecedent in the area now occupied by the Shan States to the Himalaya proper. The final phase of local sedimentation took place in the isolated lake basins of Plio-Pleistocene age and is still in progress, characterised by the formation of lignite seams, mainly from peaty deposits formed by the rapid growth and decay of aquatic and semi-aquatic plants *in situ.*

## ECONOMIC GEOLOGY.

### Coal.

Lists of the localities where coal of Jurassic age occurs have been given in the notes dealing with those rocks. Of the northern exposures in the Panlaung valley, one alone is promising enough to warrant prospecting.

The complicated structure, caused by acute folding, at places accompanied by overthrusting and shear-faulting, together with the rarity of good rock exposures, makes it impossible to trace the seams of this field on the surface or to make predictions of their possible extent.

According to C. S. Fox, the Loi-an Coal Measures form a narrow strip barely 400 yards wide along the line of a north and south fault, along which they have been let down to the west, resulting in a great degree of twisting and buckling of the strata in the Loi-an area.

About 1922, a concern known as the Coal-fields of Burma Limited, undertook very extensive prospecting operations on the Loi-an field, a great deal of trenching was done on the outcrops, while shafts were sunk and galleries driven on the more promising occurrences. Although a certain amount of coal was proved, these operations were quite unsuccessful from a commercial point of view.

In our opinion the views expressed by E. J. Jones in 1885 have not been challenged by any later evidence, when he wrote,

> 'The seams are exceedingly irregular; that is to say, they are not to be depended upon to extend to any distance. A large proportion of the coal consists of mere pockets, and even where this is not immediately evident, and they can be traced for any distance, they are found either to thin out altogether or to decrease considerably in thickness.'[1]

[1] *Rec. Geol. Surv. Ind.*, XX, p. 185, (1887).

Jones' experience included both the Minpalaung (20° 50′ : 96° 30′) and Legaung (20° 49′ 30″ : 96° 32′ 30″) and his remarks apply with equal force to the Loi-an field. At the former locality the visible coal was 7½ feet thick, separated into two seams by shaly partings five feet in thickness. The seams at Legaung, though of fair quality, were only 1½ feet in thickness.

The carbonaceous shale of Ngot-to-yagyi (20° 54′ : 96° 30′ 30″), included by Dr. Fox as a locality in his Loi-an series of Jurassic age, has now been proved to belong to the Lower Silurian rocks of the western flank of the Pindaya range. [1]

The isoclinal folding of the Coal Measures has in places led to the duplication of outcrops and local thickenings of the seams, but it also entails their disappearance at the bases of the synclinal troughs. The extreme irregularity, high or vertical dips, contorted and faulted conditions of the seams, together with the weakness and generally broken friable and soft conditions of the enclosing rocks, would render systematic mining methods difficult, dangerous and costly. Moreover, all the Shan Jurassic coals that we have seen have been in a more or less powdery condition and it is very doubtful if they could be marketed in Burma without the preliminary treatments of washing and briquetting.

Some of the coals do not cake, others, particularly those from the Panlaung valley, yield a good hard coke. The following analyses are selected from those given in Dr. Cotter's report:—

| Locality. | Moisture. | Volatile matter. | Fixed carbon. | Ash. | REMARKS. |
|---|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. | |
| Loi-an (central) . . . | 14·25 | 31·06 | 44·82 | 10·17 | Does not cake. |
| Ditto . . . | 0·82 | 27·15 | 58·61 | 13·42 | Cakes strongly. |
| Loi-an (east) . . . . | 0·82 | 24·91 | 56·22 | 18·05 | Ditto. |
| Mylnka . . . . . | 0·64 | 22·94 | 64·70 | 11·72 | Ditto. |
| Loi-an (west) . . . . | 0·54 | 27·34 | 65·28 | 6·84 | Ditto. |
| Inwun . . . . | 2·87 | 12·31 | 77·65 | 7·77 | Does not cake. |
| East of mile 38 (Thazi-Kalaw Road). [2] | 1·22 | 29·88 | 62·51 | 6·39 | Cakes strongly. |

[1] C. S. Fox, 'The Gondwana System and Related Formations', *Mem. Geol. Surv. Ind.*, LVIII, p. 146, (1931).

[2] Quoted by C. S. Fox.

## Lignite.

It would be strange if the lake basins of Thamakan, Heho and Yawnghwe did not contain lignite, which is of common occurrence in similar situations elsewhere and when it is remembered that the lakes themselves, if we may judge from those still in existence, become rapidly filled in by luxurious growths of aquatic and semi-aquatic plants which on their decay form thick beds of peat. It happens however that sections through these lake basins exposing the lacustrine deposits to any depth are non-existent, and it is only the accidental erosion in a shallow stream-bed in the Thamakan plain, at a point half a mile south-west of Nangon near Poila, and at another place in the same neighbourhood, 1¾ miles west by south of Nangon, that has revealed their presence. To Middlemiss, who examined the localities, it seemed probable that a more or less continuous layer of the lignite—neither very pure nor very thick—, existed hereabouts.

In the Tigyit valley, to the south of the Thamakan plain, a similar accident has displayed thin superficial bands of lignite in the old lacustrine deposits of that area. The section given by E. J. Jones was as follows:—

| | Feet. |
|---|---|
| Surface soil | 2 |
| Lignite | 2 |
| Brown clay | 2 |
| Lignite | 2 |
| Brown clay | 4 |

The composition of the material was:—

| | Per cent. |
|---|---|
| Moisture | 22·74 |
| Volatile matter | 36·26 |
| Fixed carbon | 30·22 |
| Ash | 10·78 |

It did not cake.

## Gold.

For a long time past gold has been known to the inhabitants of the place to occur on the western slopes of the Mwe-daw hill-mass (20° 39′ : 96° 28′ 30″), and evidence of former activity for the recovery of the metal is met to this day in the few pits dug about

halfway down the slope into and along beds of marble and siliceous limestones. Its presence in the soil derived from the above rocks was also fully known, as is indicated by the numerous tailing dumps scattered over the area, where pan-washing was practised.

Just before the Great War systematic prospecting on modern methods was started on the field and dilapidated remains of four horizontal tunnels exist to this day, but the description of persons responsible as well as the record of their activities is unfortunately nowhere available.

Since then the area has been on license, renewed continuously, but no serious effort has been made to evaluate the amount of gold or investigate the possibilities of its exploitation till last year, when Mr. E. C. M. Garrett of the Shan States Silver-Lead Corporation, Ltd., Bawzaing, acquired the prospecting licence.

At present a detailed investigation is being carried on, the old tunnels have been cleared and representative samples submitted to quantitative analyses with, it is reported, encouraging results.

The origin of the gold is intimately connected with the intrusion of diorite and granite into the Coal Measures. An almost continuous but irregular outcrop of diorite has been traced from a point a little south-east of Mwe-daw to the latitude of Law, a straight distance of about four miles to the N. N. W., which is also the direction of strike of the Coal Measures. Generally it crops out along the eastern limit of the limestone bands believed to be interbedded with the shales and siltstones of the Coal Measures here, although they bear a strong resemblace to certain types of the Plateau Limestones. In the deep ravine sections diorite is often seen capped by layers of altered limestone. The rock is propylitised, porphyritic and holocrystalline, and is made up mostly of large phenocrysts of zoned and partially saussuritised felspar and hornblende.

Typical biotite-granite has been found only at one place, north-east of Mwe-daw, separated from limestone bands by diorite.

The country rocks have been considerably affected by the intrusions both thermally and metasomatically, and, judging by the extensive silicification of the limestones, there must have been a good deal of free silica solution, which it is believed was the gold-carrier, associated with the intrusions. The limestones have either been completely silicified or are turned into marble, and a large quantity of wollastonite has been produced, and the shales and siltstones

have been turned into hard flint-like rocks still showing their lines of bedding.

Gold is by no means uniformly distributed throughout the silicified limestone nor is it confined to them, but it almost always occurs disseminated in a very fine state hardly visible to the naked eye even in the pan concentrates. Some of the marbles are reported to have yielded good values and wollastonite on the whole is considered quite hopeful.

Though lying to the north of the area under description, it is as well to mention here that Middlemiss records the occurrence of gold on a hill in the Baw State between the Zawgyi *chaung* and the Myitnge (Nàm-Tu). The hill is about 3,000 feet high and lies about ten miles north-east of Myogyi.[1] The metal is in the form of dendritic crystals and flakes in cavities of quartz which probably forms veins in the local gneissic rock.

## Copper.

Antimonial tetrahedrite with the green and blue carbonates of copper and containing small quantities of arsenic, iron, zinc, lead and silver, occurs at a number of isolated places about Ya-taung (20° 59′ : 96° 35′), the 5,907 feet peak which lies in the Pindaya beds, and about five miles due south, near Myindwin (B. 1). Slightly to the north of this peak occur the interbedded rhyolites to which attention has been drawn earlier.

At the time of Middlemiss's expedition surface workings were being carried on at Ganaingywa, 1½ miles due south of Ya-taung, the ore occurring in thin veins dipping W. N. W. at 30° and following the bedding of the limestone on the eastern slope of the hill.

Other occurrences exist on Mené-taung and near Alè-chaung, to the north-east and north-west of Ya-taung, respectively. From the walls of an old Chinese shaft near Alè-chaung, Sondhi collected specimens of bedded limestone containing small strings and nodules of galena with malachite and azurite.

On the eastern limb of the Pindaya inlier small old copper workings are known at Kye-dwin-gon about 2½ miles S. S. W. of Pindaya, and Sondhi observed a barytes vein one mile due west of Zawgyi (20° 59′ : 96° 40′), bearing stains of copper and thin stringers of malachite.

[1] *Loc. cit.*, p. 151.

About half a mile to the north of Heho and about 150 feet above the plain in the first valley to the north of the one which carries the road and railway across the Heho range, there is an old shaft 30 or 40 feet deep and the dumps from two or three collapsed adits. On these vein quartz and shaly fragments of rock occur, containing chalcocite and films of malachite and azurite. To the south-east of Heho, the blue and green carbonates of copper are also found as thin films on shaly outcrops near peak 4,268 feet, east of Pein-ne-bin.

Copper-ore is known to occur in the neighbourhood of Mwe-daw associated with the gold-bearing rocks. Specimens of metamorphosed limestone examined by us from this locality contained both chalcopyrite and malachite.

Copper-ore, presumably the yellow sulphide, is also reported from the beds of streams running to Kwe-ma-sa, south of Nampandet.

## Antimony.

Stibnite occurs in a few places in the neighbourhood of Menè-taung (20° 59′ : 96° 37′). It was worked in a small way just to the south of the village, where it occurs in small groups of radiating acicular crystals and columnar blades in a highly decomposed limestone.

## Iron-ore.

Impure iron-ore of a lateritic character occurs in small quantities on the surface at various localities in Poila and Mawsön States, but they do not appear to be of any economic importance. Scattered pisolites of limonite are common in the red residual clay of the *karst* plateau areas and ferruginous laterite at the margins of the old lake basin.

On the south-eastern slopes of the Heho range to the east of Mawnang there are scattered occurrences of iron slags dating from a time when the surface iron-ores of the locality were melted on a small scale by the Shans. To-day the slag is used for road dressing, about four miles of local road being coated with it.

## Iron Pyrites.

According to Middlemiss iron pyrites was mined for the manufacture of sulphur at Yebok in the Poila State. This local industry has been extinct for many years.

Crystals of pyrite are common in some of the shales of the Coal Measures series, and the diorite intrusion at Mwe-daw is at places impregnated with it.

## Wolfram.

A concession about three-quarters of a mile in extent was granted for wolfram mining a few years ago on the west and south-western flanks of hill 4,832, east of Paw-lamaw, a village near the southern extremity of the Heho plain (20° 37′ 30″ : 96° 49′). Here there are numerous dumps from trenches and Shan pits, which are mainly made up of hard siltstones and fragments of shale. Many of them are crossed by thin quartz stringers from an eighth of an inch upwards to veinlets four or five inches across, which appear to have been derived from a stock-work. The quartz is granular and crystalline, occasionally exhibiting irregular vugs. The veinlets contain muscovite mica, generally as a selvedge. Wolfram occurs in thin plates and crystals sparsely and irregularly distributed through the quartz and is usually very decomposed. The limestones of the vicinity, which belong to the Mawsön series of Ordovician age, are of the tabular type with argillaceous partings and dip W. S. W. at 35°. Their only differences from the typical varieties consist in their white, somewhat saccharoidal character and in the development of a little fine-grained white mica. These changes are perhaps a result of metamorphism consequent on the intrusion of the quartz-mica-wolfram veins and stock-works. Judged from the old workings, the latter occur in a broad zone running approximately north and south and a few hundred feet wide. The only other mineral noted in association with the veins is cubical pyrite altering to limonite.

## Lead and Silver.

An indigenous mining and metallurgical industry concerned with lead and silver flourished for centuries in the Mawsön State until it was extinguished by the annexation of Upper Burma in 1886 and the consequent prohibition of the export of lead from the Shan States.

In several more or less parallel zones which stretch for many miles north and south through Mawsön and across the borders of the adjoining state of Lawksawk, there are thousands of ancient

pits—the number being used in its literal sense—small in section, often barely big enough for a man to enter, which descend into the thick residual clay and into the fissures and partings of the underlying limestone, or are excavated in the sedimentary horizons which occasionally separate the thicker limestone bands of the Mawsön series. Workings which have been cleaned out and explored have been found to ramify in all directions and to have been carried in some cases to lengths of hundreds of feet and occasionally to depths of 200 or 300 feet vertically below the surface. Where they are close together, as sometimes happens, the burrowed ground resembles a rabbit warren on a large scale.

In a recent paper Coggin Brown has described the lead-ore deposits of Mawsön in detail and to that reference should be made for fuller accounts than it is possible to give here.[1]

The western limit of the lead-bearing region may be taken as a line running north and south through Te-thun (20° 58′ : 96° 46′) and Kyein-daw (20° 56′ : 96° 46′). It is characterised by the occurrence of scattered accumulations of slags rather than by old workings. The most northerly workings in Mawsön are near Si-set (21° 0′ : 96° 49′), while further north still in the Na Kyawng Circle of Lawksawk argentiferous galena was extensively mined in bygone generations.

On the east, the limit of the area which has attracted modern capitalistic enterprise lies on and about longitude 96° 50′ and stretches from a point about one mile north of Ywa-haung-gyi (20° 58′ : 96° 50′) through Ta-da-gon to the neighbourhood of Kanni, a distance of ten miles, of which the greater part lies in the Kyawktap Circle of Yawnghwe State. Other groups of old workings are known to occur however, in the area between longitude 96° 50′ and the edge of the Mawsön highlands about longitude 96° 55′.

The latitude of Kanni—a village about 1½ miles E. N. E. of Kyawktap—marks the southern limit of the area which has attracted the attention of the modern miner.

Within this region many prospecting pits and hill-side adits have been made in various places by recent adventurers. In most of these cases the work has been fruitless from an economic point of view but in three of them, Bawdwinja, Bawzaing, and the Lawksawk Sawbwa's mine,[2] ore-bodies have been discovered.

[1] Coggin Brown, 'The Geology and Lead Ore Deposits of Mawsön, Federated Shan States', *Rec. Geol. Surv. Ind.*, LXV, pp. 394-433, (1931).

[2] About three-quarters of a mile W. S. W. of the peak 5,473 feet, the highest point of the Mawsön upland.

The main ore-body of the Bawzaing mine—leased by the Shan States Silver-Lead Corporation, Limited—occurs in a wide, nearly vertical, irregular fissure with ragged walls, trending approximately N. 20° W. obliquely across the strike of the country-rocks. The fissure is filled with mineralised clay containing irregular limestone blocks of all sizes. Within this fissured zone there is an ore-shoot with a decided pitch to the south and of very varying width, up to a maximum of 70 feet. The ore-shoot was encountered in the Bawzaing shaft at about 75-80 feet from the surface, but in the Theingon shaft, 750 feet away, it was not met with until a depth of over 124 feet was reached. It varies between 175-200 feet in height and, thinning out both above and below, displays a roughly lenticular section, as the main fissure pinches in at both the northern and southern ends of the ore-shoot. Other ore channels are known to exist but are as yet imperfectly explored. The Bawzaing shaft is 400 odd feet in depth with levels at 120, 200 and 331 feet respectively; the 400-foot level is reached by a winze from the 280-foot level. The Theingon shaft is 575 feet deep with five corresponding levels from it. The mine is equipped with Diesel power-plant, electric winders and pumps and possesses an up-to-date mill.

The ore-reserves in sight in April. 1930, were placed at 185,400 tons, averaging over 7 per cent. of lead. Operations are at present suspended owing to the depression in the base metal market.

Galena is irregularly distributed in the clay of the fissure which also contains much cerrusite in earthy and powdery forms. An assay of the concentrates (over quarter-inch material) yielded Pb 0·75 per cent., Ag 14 ozs., Zn 0·30 per cent. There is a good deal of evidence of the occurrence of ore *in situ* underground, which has been detailed in the paper referred to above, in which the various theories which have been advanced to account for the origin of these ore-deposits are discussed at length.

In a series of 13 assays of ores from various parts of Mawsön made by a reliable British firm, the average value of the silver content was 22 ozs. silver per ton of lead, the lowest value 12 ozs. and the highest 45 ozs.

During periods when high prices have ruled in the lead market, the collection and export of the ancient slags has been profitably carried on and some thousands of tons have been shipped abroad. The lead content of five samples of slag collected and analysed by the Geological Survey of India ranged from 36·5 to 40·3 per cent.

The slags carry very little silver, as it was for this metal that the ores were originally treated by the ancients.

Small quantities of lead slag are shipped to Burma under the name of *bwet*, where they are used as a glaze for earthenware pottery.

## Barite.

Well-developed veins of barite, carrying galena, occur at Thaungdwin near Tan-tape (20° 59′ : 96° 50′) in Lawksawk State.

A thick barite veins crops out across the footpath from Kyeindaw to Mawsön just before the descent into the valley which carries the motor road from Heho to Mawson.

Half a mile east of Kônleau the weathered outcrop of a massive barite vein can be traced for 40 yards, the scattered fragments of which cover a width of ten feet in the surface soil. This locality and the second one described above are easy of access, the veins appear to be large as far as surface indications go, and are worth further exploration in case a demand for the mineral arises in Burma. Barite is already used to a certain extent on the oilfields as a weighting material in the preparation of heavy muds.[1]

## Limestones and Building Materials.

Limestones of a great variety of composition, colour and texture exist in the area under description. The dark blue-grey kinds of the Upper Plateau Limestones and the purer bands of the argillaceous Silurian and Ordovician stones are trimmed into blocks and used for bridge-building or occasionally for house foundations; they are also broken for road metal. Some of the pink, chocolate and green banded types of Silurian age would doubtless form serviceable ornamental stones but there is little demand for building stone in the Shan States. The brecciated dolomites of the Lower Plateau 'Limestones' are too shattered and pulverised for these purposes, but are quarried as a surface dressing for roads, which quickly breaks to dust in the dry weather and gives rise to a slippery coating of slimy mud in the rainy season.

[1] A. L. Coulson, *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, pp. 122-125, (1933).

The domestic indigenous architecture from the palace of the chief and the monastery of the priest to the house of the peasant, finds its expression entirely in wood and to a preponderating extent amongst the poor, in bamboo.

On the drier edges of the Heho and Thamakan plains under the surface soil, in the belt of gently rising ground as the slope towards the surrounding hills begins, a pisolitic, ferruginous laterite sometimes grows, generally in small patches. We have seen these excavated, trimmed into blocks and used for culverts and house foundations. Like other laterites this material possesses the property of slowly hardening on exposure.

The harder varieties of travertine are also dressed for building purposes, particularly in the Yawnghwe and Hopong valleys, and the harder beds of sandstones of the Red Beds and the Coal Measures are often used in buildings and culverts.

The local pagodas, the houses of Europeans in Kalaw and Taunggyi and most of the Government buildings in the States are built mostly of brick, only a little of the harder varieties of Plateau Limestones being used. Clays good enough for brick manufacture exist in many places. In the construction of pagodas a pit is usually opened in the vicinity, and bricks, moulded by hand, are burnt on the spot, while a limestone outcrop, which is usually not far away, furnishes the stone for lime and whitewash afterwards.

Some of the deeply tinted clays into which the argillaceous limestones of the older Palæozoic rocks weather would form bases for useful colour-washes, if any demand for such things existed.

In the gold-bearing area at Mwe-daw a large amount of almost pure limestone has been turned into marble around the dioritic intrusions. Various types of the rock are to be seen, varying in texture from fine sugary to coarse crystalline and in colour from light slaty grey to pure white. Some of the types could perhaps be found marketable.

## EXPLANATION OF PLATES.

PLATE 6. Thrust plane in the Coal Measures.

PLATE 7, FIG. 1. 'Rain pillar' weathering of the lacustrine deposits near Aungban.

FIG. 2. Lacustrine deposits lying on the ragged edges of the Plateau Limestone.

PLATE 8, FIG. 1. Travertine dams in the Panlaung *chaung*.

FIG. 2. A typical section of the Coal Measures.

PLATE 9, FIG. 1. The Taunggyi Crag (Plateau Limestone), with the bungalow of the Commissioner of the Federated Shan States in the foreground (since destroyed by fire).

FIG. 2. Contorted shales and siltstones of the Mawsŏn series east of Heho.

PLATE 10, FIG. 1. View of the Taunggyi hills from the Yawnghwe valley.

FIG. 2. A view of the Pindaya beds (in the background). Note the topographical difference of the area occupied by the Plateau Limestone in the foreground and the Pindaya beds in the background.

PLATE 11. Geological map of the Kalaw-Taunggyi area, Southern Shan States. Scale 1 inch=4 miles.

MGIPC—M—VIII-4-9—4-1-34—850.

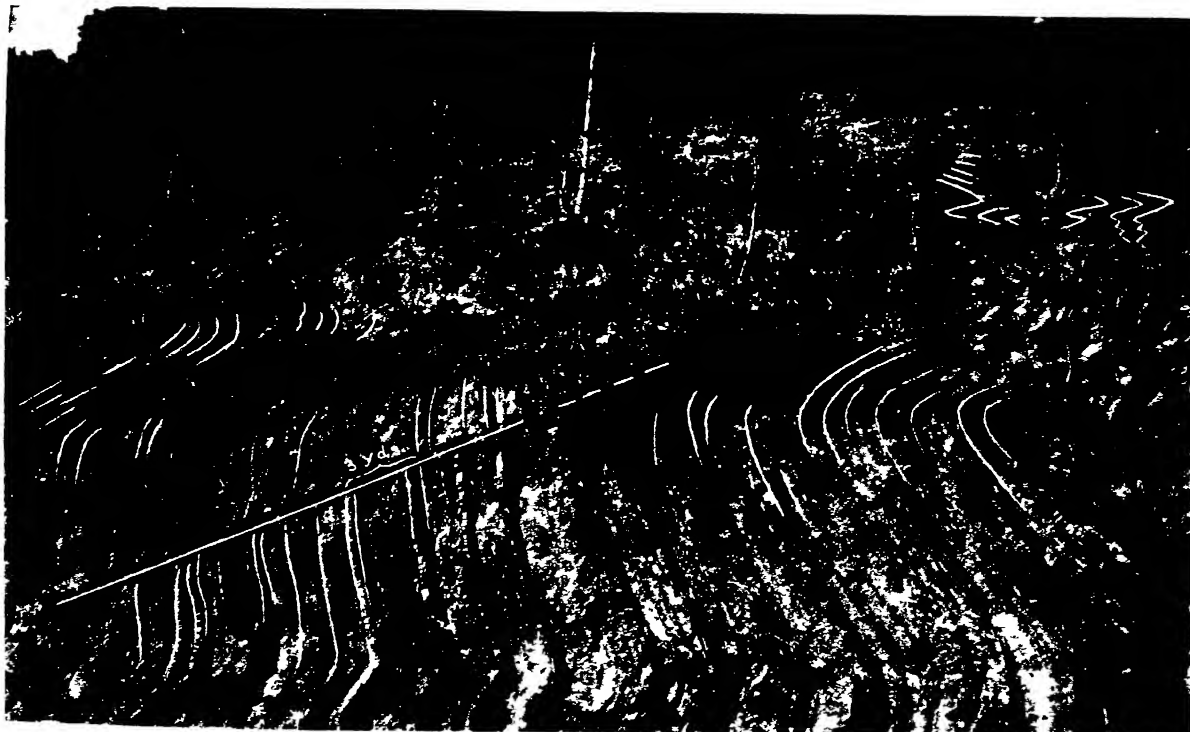
FIG 1 CLOSE VIEW OF THE PHACOIDAL LIMESTONES INTERBEDDED WITH MUDSTONES AT LOILEM, SHOWING THE CHARACTERISTIC PATTERN

V P. Sondhi, photos G S I, Calcutta

FIG 2. PANORAMIC VIEW OF THE SILURIAN DEPOSITS AT LOILEM, WITH LIMESTONES FULL OF POT-HOLES IN THE BACKGROUND

*V. P. Sondhi, photo* *G. S. I., Calcutta*

CALCAREOUS GROWTHS IN THE HTAMSANG CAVES.




*V. P. Sondhi, Photo.*

*G. S. I., Calcutta.*

THRUST PLANE IN THE COAL MEASURES.

FIG 1 'RAIN PILLAR' WEATHERING OF THE LACUSTRINE DEPOSITS NEAR AUNGBAN


*V. P Sondhi, Photos.* *G. S I, Calcutta*

FIG. 2. LACUSTRINE DEPOSITS LYING OVER THE RAGGED EDGES OF THE PLATEAU LIMESTONE.

FIG 1 TRAVERTINE DAMS IN THE PANLAUNG *CHAUNG*

*V. P. Sondhi, Photos* *G S I, Calcutta*

FIG 2 A TYPICAL SECTION OF THE COAL MEASURES

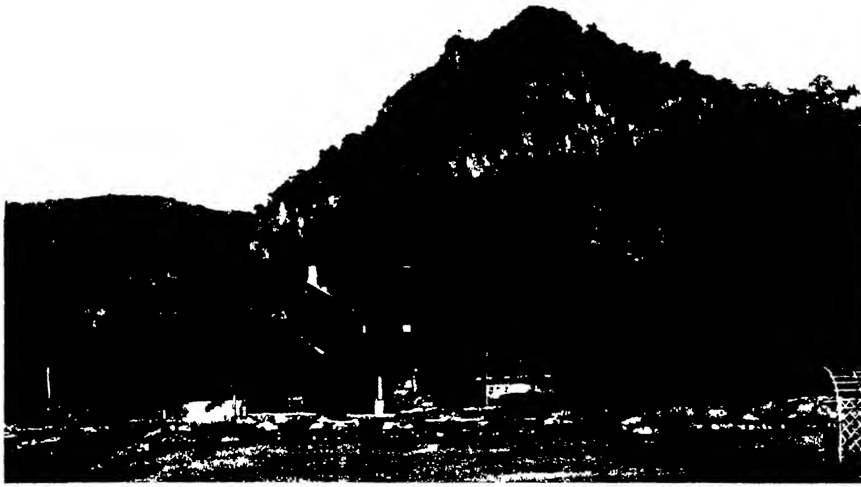
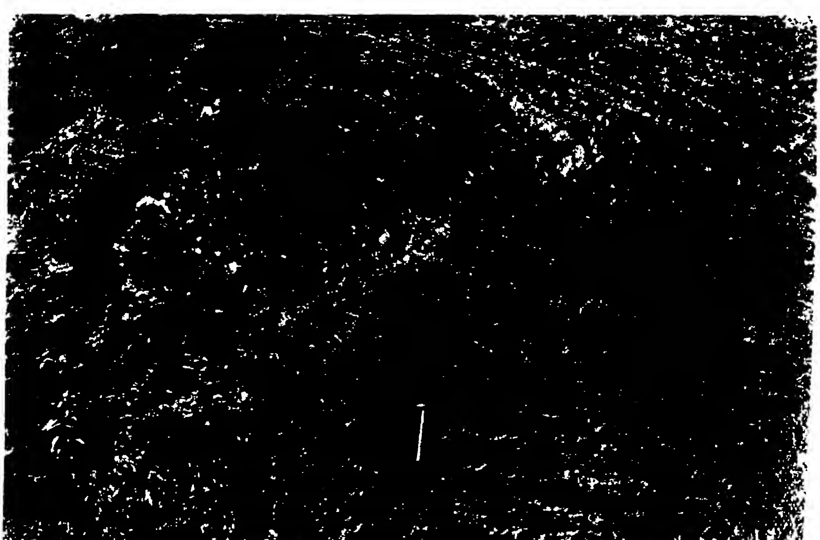


FIG. 1. THE TAUNGGYI CRAG FORMED OF PLATEAU LIMESTONE
The bungalow of the Commissioner of the Federated Shan States, since destroyed by fire, is in the foreground.



*V. P Sondhi, Photos.* *G. S. I., Calcutta.*

FIG. 2. CONTORTED SHALES AND SILTSTONES EAST OF HEHO (MAWSON SERIES).

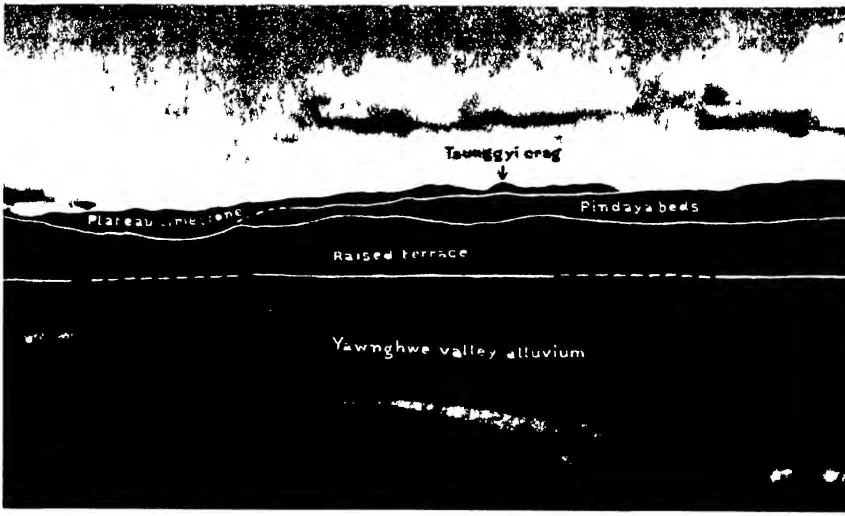



FIG. 1. VIEW OF THE TAUNGGYI HILLS FROM THE YAWNGHWE VALLEY


*V. P Sondhi, Photos* *G. S I, Calcutta.*

FIG. 2. VIEW OF THE PINDAYA BEDS (IN THE BACKGROUND).

# RECORDS

OF

# THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1933 [ September


## THE MINERAL PRODUCTION OF INDIA DURING 1932. BY L. L. FERMOR, O.B.E., D.Sc., A.R.S.M., F.G.S., F.A.S.B., M. INST. M.M., *Director, Geological Survey of India.*

CONTENTS.

## I. INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these *Records* (Vol. XXXII, 1905), although admittedly not entirely satisfactory, is still the best that can be devised under present conditions. As the methods of collecting the returns become more precise, and the machinery employed for the purpose more efficient, the number of minerals included in Class I—for which approximately trustworthy annual returns are available—increases, and it is hoped that the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will in time be reduced to a very small number. In the case of minerals still exploited chiefly by primitive Indian methods and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible ; the total error from year to year, however, is characterised by some degree of constancy, and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small indigenous alluvial industry contributes such an insignificant portion to the total outturn that the error from this source may be regarded as negligible.

The average value of the Indian rupee during the year 1931 was 1*s.* $6\frac{1}{16}$*d.*; the highest value reached was 1*s.* $6\frac{5}{32}$*d.* and the lowest 1*s.* $5\frac{7}{8}$*d.* The values for 1932 shown in the tables are given on the basis of 1*s.* $6\frac{1}{16}$*d.* to the rupee ; for ease of calculation, £1 has been taken to be equivalent to Rs. 13·3 instead of Rs. 13·287.

Table 1 shows the total value of minerals for which returns of production are available for the years 1931 and 1932. The average figure for the quinquennium, 1919-23, was £25,194,123. In the following year, 1924, there was an apparent increase of over £3,500,000 ; this was, in part, however, due to the higher average value of the rupee during that year. Since 1924, there has been a steady decline, which persisted down to the year 1928, for which the value was £21,888,528. There was an arrest in this decline in 1929, which showed an increase in total value to £22,328,686 or about 2 per cent. over that of 1928. In 1930, however, the decline was resumed and the total value of the production fell by

TABLE 1.—*Total value of Minerals for which returns of production are available for the years 1931 and 1932.*

| — | 1931 (£1= Rs. 13·5). | 1932 (£1= Rs. 13·3). | Increase. | Decrease. | Variation per cent. |
|---|---|---|---|---|---|
| | £ | £ | £ | £ | |
| Coal | 6,125,804 | 5,120,045 | .. | 1,005,759 | —16·4 |
| Petroleum | 4,380,389 | 3,818,875 | .. | 561,514 | —12·8 |
| Gold | 1,540,885 | 1,906,123 | 365,238 | .. | +23·7 |
| Salt | 1,010,441 | 898,754 | .. | 111,687 | —11·1 |
| Lead and lead-ore (*a*) | 939,906 | 820,109 | .. | 119,797 | —12·7 |
| Building materials | 851,741 | 685,877 | .. | 165,864 | —19·5 |
| Silver | 387,351 | 471,557 | 84,206 | .. | +21·7 |
| Tin-ore | 259,806 | 339,097 | 79,291 | .. | +30·5 |
| Copper-ore and matte | 407,181 | 338,675 | .. | 68,506 | —16·8 |
| Iron-ore | 308,055 | 294,720 | .. | 13,335 | —4·3 |
| Mica (*c*) | 307,316 | 251,800 | .. | 55,516 | —18·1 |
| Manganese-ore (*b*) | 726,954 | 140,022 | .. | 586,932 | —80·7 |
| Zinc concentrates | 127,669 | 113,481 | .. | 14,188 | —11·1 |
| Saltpetre (*c*) | 73,414 | 92,272 | 18,858 | .. | +25·7 |
| Nickel-speiss | 49,924 | 77,269 | 27,345 | .. | +54·8 |
| Ilmenite | 41,991 | 58,134 | 16,143 | .. | +38·4 |
| Tungsten-ore | 65,309 | 52,921 | .. | 12,388 | —18·9 |
| Jadeite (*c*) | 26,094 | 28,359 | 2,265 | .. | +8·7 |
| Chromite | 23,335 | 20,727 | .. | 2,608 | —11·2 |
| Clays | 25,615 | 19,451 | .. | 6,164 | —24·1 |
| Refractory materials | 5,108 | 10,100 | 4,992 | .. | +97·7 |
| Steatite | 9,001 | 9,736 | 735 | .. | +8·2 |
| Gypsum | 7,254 | 7,125 | .. | 129 | —1·8 |
| Antimonial lead | 14,781 | 6,627 | .. | 8,154 | —55·2 |
| Monazite | 890 | 6,147 | 5,257 | .. | +590·7 |
| Magnesite | 2,026 | 5,470 | 3,444 | .. | +169·9 |
| Diamonds | 2,569 | 5,428 | 2,859 | .. | +111·3 |
| Zircon | 7,972 | 3,805 | .. | 4,167 | —52·3 |
| Fuller's earth | 2,542 | 3,405 | 863 | .. | +33·9 |
| Ochre | 1,918 | 2,489 | 571 | .. | +29·7 |
| Barytes | 3,200 | 2,209 | .. | 991 | —30·9 |
| Asbestos | 5 | 677 | 672 | .. | .. |
| Beryl | .. | 397 | 397 | .. | .. |
| Felspar | 247 | 330 | 83 | .. | +33·6 |
| Amber | .. | 146 | 146 | .. | .. |
| Apatite | 79 | 81 | 2 | .. | +2·5 |
| Soda | 31 | 33 | 2 | .. | +6·4 |
| Garnet (*d*) | .. | 28 | 28 | .. | .. |
| Bismuth | 6 | 4 | .. | 2 | —33·3 |
| Ruby, sapphire and spinel. | 3,175 | .. | .. | 3,175 | .. |
| Serpentine | 6 | .. | .. | 6 | .. |
| Columbite | 4 | .. | .. | 4 | .. |
| TOTAL | **17,739,994** | **15,612,505** | **613,397** | **2,740,886** | *—12·0* |
| | | | $\underbrace{\qquad\qquad\qquad}_{-2,127,489}$ | | |

(*a*) Excludes antimonial lead. (*b*) Export f.o.b. values. (*c*) Export values. (*d*) Estimated.

over £2,500,000 to £19,750,233, this continuing in 1931, by over £2,000,000, to £17,739,994, and again in 1932 by over £2,000,000, to £15,612,505. Of each of the thirteen minerals with a value of over £100,000 annually, an enormous percentage fall in value is shown by manganese-ore (80·7 per cent.), whilst smaller falls are shown by mica (18·1 per cent.), copper-ore and matte (16·8 per cent.), coal (16·4 per cent.), petroleum (12·8 per cent.), lead and lead-ore (12·7 per cent.), salt and zinc concentrates (each 11·1 per cent.), building materials (7·9 per cent.), and iron-ore (4·3 per cent.); while large increases are shown by tin-ore (30·5 per cent.), gold (23·7 per cent.), and silver (21·7 per cent.). Amongst less important minerals the largest increases in value are shown by nickel-speiss, saltpetre, ilmenite, monazite, refractory materials, magnesite, diamonds, and jadeite; whilst the most important decreases are shown by tungsten-ore, antimonial lead, zircon, ruby sapphire and spinel, and chromite. An increase or decrease in value does not always correspond to a similar variation in output, and cannot, therefore, be regarded as an infalliable indication of the state of an industry. But in 1932, in all cases, with four exceptions, an increase or decrease of value accompanied an increase or decrease of production. The exceptions were gold, in which a small decrease in output was accompanied by a large increase in value; and iron-ore, petroleum and gypsum, in which increases in output were accompanied by decreases in total value.

It is interesting to compare the changes in the figures of total value recorded in Table 1 with the variations in the average annual value of the leading metals and ores as summarised in Table 2. In 1931 all the metals and ores given in this table showed a fall in price except gold, in the price of which there was a substanial rise. In 1932 there was a very large rise in the price of gold, and in addition a partial recovery in the price of spelter, tin and silver.

The number of mineral concessions granted during the year under review amounted to 327 against 351 in the preceding year. Of these 26 were quarry leases, 249 were prospecting licenses, and 52 were mining leases. This small total compared with the figure (714 mineral concessions) for 1927 is an index of the decreased prospecting and private geological enterprise that accompanies a period of depression.

TABLE 2.—*Average prices in the United Kingdom of Principal Metals and Ores during the years 1931 and 1932.*

| — | 1931. £ per ton. | 1932. £ per ton. |
|---|---|---|
| *Metals—* | | |
| Copper, standard | 38·39 | 31·73 |
| Lead, pig, soft foreign | 13·03 | 12·04 |
| Spelter, ordinary | 12·44 | 13·69 |
| Tin, standard | 118·45 | 135·94 |
| Pig-iron, Cleveland No. 3 | 2·93 | 2·92 |
| Steel rails | 8·38 | 8·37 |
| Ferro-manganese | 11·25 | 11·25 |
| Gold, fine, per ounce | 92·492 sh | 118·037 sh. |
| Silver, standard, per ounce | 14·665 *d.* | 17·834 *d.* |
| *Ores—* | | |
| Chromite, 48·57 per cent., per ton | (*a*) £ 4·055 | £4·698 |
| Manganese-ore, first grade, per unit | 11·7 *d.* | 9·5 *d.* |
| Wolfram, per unit | 13·59 sh. | 12·31 sh. |

(*a*) 48·55 per cent.

In Part 4 of the previous volume of these *Records* is a paper giving tables of production, imports, exports, and consumption of minerals and metals in India for 1913, 1917, 1920 and 1926 to 1931.

These data are given in considerable detail and similar data could not easily be obtained in full in time for incorporation in successive annual reviews of mineral production without causing undue delay. It is possible, however, to bring up-to-date Table V of that review showing the quantities of ores, metals and other mineral products available for consumption in India. These data are summarised in Table 3 of this present Review.

TABLE 3.—*Consumption, 1932.*

| Ores and minerals. | Kinds and grades. | Unit. | Production. | Retained imports. | Exports of domestic production. | Minerals ores and metals available for consumption. Columns 3+4−5. |
|---|---|---|---|---|---|---|
| 1 | 2 | 2a | 3 | 4 | 5 | 6 |
| Aluminium | Aluminium unwrought (ingots, blocks etc.). | Cwts. | .. | 238 | .. | 238 |
| Antimony | Antimonial lead | Tons | 642 | .. | (a) | .. |
| Arsenic | Metal and oxides | Cwts. | (b) | 2,649 | .. | 2,649 |
| Asbestos | Chrysotile and other kinds. | Tons | 90 | .. | (c) | .. |
| Barytes | .... | Tons | 2,957 | 2,173 | .. | 5,130 |
| Beryl | .... | Tons | 281 | .. | (c) | 281 |
| Bismuth | Mostly native | Lbs. | 27 | .. | .. | 27 |
| Borates | Borax (including boracic acid). | Cwts. | .. | 29,197 | .. | 29,197 |
| Brass | .... | Tons | 5,440 | (d)27,600 | (d) 281 | 32,759 |
| Clays | Clays other than China clay. | Tons | 117,387 | .. | .. | 117,387 |
| | China clay | Tons | 13,497 | 19,537 | .. | 33,034 |
| Chrome-ore | Chromite | Tons | 17,865 | .. | (e) 25,638 | .. |
| Coal, coke and bye-products. | Bituminous non-coking coal, bituminous coking coal, anthracite. | Tons | 20,153,387 | 47,544 | 519,483 | 19,681,448 |
| | Coal-tar and pitch | Tons | 44,857 | 4,312 | .. | 49,169 |
| | Sulphate of ammonia | Tons | 9,474 | 32,640 | 303 | 41,811 |
| Copper | Metal unwrought | Tons | 4,443 | 129 | .. | 4,572 |
| Copper-matte | .... | Tons | 9,729 | .. | (f)11,251 | .. |
| Diamonds | .... | Carats | 1,254·1 | (g) | .. | 1,254·1 |
| Ferro-manganese | .... | Tons | 366 | .. | .. | 366 |
| Ferro-alloys | .... | Tons | .. | 495 | .. | 495 |
| Felspar | .... | Tons | 473 | .. | .. | 473 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Fuller's earth | .... | Tons | 4,359 | .. | .. | 4,359 |
| Garnet sand | .... | Tons | 147 | .. | (*h*) | .. |
| Gold | .... | Fine ounces. | 329,682 | 201,011 | (*i*)9,666,122 | *Nil* |
| Graphite | .... | Tons | 5 | 203 | .. | 208 |
| Gypsum | .... | Tons | 54,741 | .. | .. | 54,741 |
| Ilmenite | .... | Tons | 50,052·5 | .. | (*h*) | .. |
| Iron | Ore | Tons | 1,760,501 | .. | .. | .. |
| | Pig | Tons | 913,314 | 497 | 250,137 | 663,674 |
| | Steel | Tons | 430,333 | 91,077 | .. | 521,410 |
| | Manufactures of iron or steel other than those included under 'Steel.' | Tons | 20,637 | 180,272 | 102,328 | 98,581 |
| Jadeite | .... | Cwts. | 3,026 | .. | 3,345 | .. |
| Lead | Ore | Tons | 372,586 | .. | .. | .. |
| | Pig | Tons | 70,560 | 157 | 61,361 | 9,356 |
| Magnesite | .... | Tons | 13,864 | .. | (*h*) | .. |
| Manganese-ore | .... | Tons | 212,604 | .. | (*j*) 301,252 | .. |
| Mica | .... | Cwts. | 32,713 | 195 | 47,021 | *Nil* |

(*a*) Known to be exported, but export figures are not available.

(*b*) Known to be produced, but production figures are not available.

(*c*) Probably exported.

(*d*) Including bronze and similar alloys.

(*e*) Includes 4,998 tons of chromite produced in British India, exported from Mormugao in Portuguese India.

(*f*) It is presumed that of this figure, 11,194 tons representing 'copper-wrought, other' refer to copper-matte, the whole of which is exported for smelting abroad.

(*g*) Quantity not known. Value of diamonds imported in 1932 amounted to Rs. 56,86,619.

(*h*) Known to be exported, but export figures are not available.

(*i*) Total exports, largely imported in previous years.

(*j*) Includes 108,508 tons produced in India but exported from Mormugao, a port in Portuguese India.

### TABLE 3.—*Consumption, 1932.*

| Ores and minerals. | Kinds and grades. | Unit. | Production. | Retained imports. | Exports of domestic production. | Minerals ores and metals available for consumption. Columns 3+4−5. |
|---|---|---|---|---|---|---|
| 1 | 2 | 2a | 3 | 4 | 5 | 6 |
| Monazite | .... | Tons | 654·3 | .. | (a) | .. |
| Nickel-speiss | .... | Tons | 3,580 | .. | (a) | .. |
| Ochre | .... | Tons | 6,237 | .. | .. | 6,237 |
| Petroleum | Crude | Gals. | 308,606,031 | .. | .. | 308,606,031 |
| | Petrol including benzene and dangerous spirit. | Gals. | (b) 67,855,982 | 6,891,745 | 190 | 74,747,537 |
| | Kerosene | Gals. | 145,895,962 | 78,091,572 | .. | 223,987,534 |
| | Fuel oil | Gals. | 13,434,349 | 105,252,687 | .. | 118,687,036 |
| | Batching and lubricating oils. | Gals. | 10,723,948 | 14,339,221 | .. | 25,063,169 |
| | Paraffin wax | Tons | 49,470 | 187 | 47,108 | 2,549 |
| Phosphates | .... | Tons | 121 | 5,181 | .. | 5,302 |
| Potash minerals and chemicals including saltpetre. | Saltpetre | Cwts. | *180,382 | .. | 165,782 | 14,600 |
| | Potash chemicals and manures. | Cwts. | .. | 157,185 | .. | 157,185 |
| Quicksilver | .... | Lbs. | .. | 332,601 | .. | 332,601 |
| Refractory materials | .... | Tons | (c) 14,148 | .. | (d) | .. |
| Salt | .... | Tons | (e) 1,319,620 | 552,741 | 14 | 1,872,347 |
| Silver | .... | Ounces | (f) 6,026,737 | 5,334,960 | 34,664,148 | *Nil* |
| Steatite | .... | Tons | 6,512 | .. | .. | 6,512 |
| Sulphate of ammonia | .... | Tons | 9,474 | 32,640 | 303 | 41,811 |
| Sulphur | .... | Cwts. | .. | 323,839 | .. | 323,839 |
| Tin | Ore | Tons | 4,525 | .. | 2,420 | 2,105 |
| | Metal (unwrought) | Cwts. | .. | 49,279 | .. | 49,279 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tungsten . . . | Ore . . . . . | Tons | 2,022·9 | .. | 3,397 | *Nil* |
| Zinc . . . | Concentrates . . | Tons | 44,484 | .. | 49,950 | *Nil* |
| | Metal (unwrought) . | Tons | .. | 15,306 | .. | 15,306 |
| | Metal (wrought) . . | Tons | .. | 1,417 | .. | 1,417 |
| Zircon . . . | .... | Tons | 490·6 | .. | (*a*) | .. |

(*a*) Known to be exported, but export figures are not available.
(*b*) Includes aviation and motor spirit.
(*c*) Includes 5,555 tons of kyanite.
(*d*) Known to be exported, but export figures are not available.
(*e*) Excludes production in Aden.
(*f*) Production in fine ozs., imports and exports in standard ounces.
* 165,782 cwts. exported plus 14,600 cwt. consumed in tea gardens in India.

## II.—MINERALS OF GROUP I.

### Antimony.

The production of antimonial lead obtained as a bye-product in the lead refinery at the Namtu smelter of the Burma Corporation Limited, decreased from 1,505 tons valued at Rs. 1,99,545 (£14,781) in 1931 to 642 tons valued at Rs. 88,140 (£6,627) in 1932. This product contains approximately 72 per cent. of lead, 24 per cent. of anitmony and 4 ozs. of silver to the ton, and is exported to the United States of America for further treatment.

There has been no production of antimony-ore in the Amherst district, Burma, since 1930, when the output amounted to 3 tons valued at Rs. 60 (£4).

### Chromite.

There was a small decrease in the production of chromite in India from 19,913 tons in 1931 to 17,865 tons in 1932. This decrease is the balance of a great decrease in the output of Baluchistan amounting to almost complete cessation, a large increase in the output of Singhbhum to a figure not hitherto reached, and a recovery in the output of the Mysore district from the fall of the previous year. The total exports from India during the year were nearly twice those of the previous year and considerably in excess of the production, amounting to 25,638 tons, made up of 20,640 tons from British India and 4,998 tons from Mormugao in Portuguese India, as compared with 7,708 tons and 5,535 tons respectively in the previous year. The small decrease in production was accompanied by a small fall in the value per ton from Rs. 15·8 in 1931 to Rs. 15·4 in 1932.

Between 40 and 50 per cent. of the world's supply of chromite comes from Southern Rhodesia, which has now become the predominant source of this mineral.

TABLE 4.—*Quantity and value of Chromite produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Baluchistan—* | | | | | | |
| Zhob . . | 12,189 | 1,81,291 | 13,429 | 228 | 3,420 | 257 |
| *Bihar and Orissa—* | | | | | | |
| Singhbhum . | 2,749 | 37,269 | 2,760 | 7,638 | 1,08,972 | 8,193 |
| *Mysore State—* | | | | | | |
| Hassan . | 1,888 | 33,153 | 2,456 | 2,812 | 18,421 | 1,385 |
| Mysore . | 3,087 | 63,313 | 4,690 | 7,187 | 1,44,862 | 10,892 |
| TOTAL . | **19,913** | *3,15,026* | *23,335* | **17,865** | *2,75,675* | *20,727* |

## Coal.

There was a decrease during the year of 1,563,048 tons, or about 7·2 per cent., in the output of coal. This decrease was due mainly to Bihar and Orissa with smaller falls in Assam and Bengal and a trivial fall in Rajputana. There was a relatively large increase in the production of the Central Provinces, with smaller increases in Hyderabad, the Punjab and Central India and a trivial increase in Baluchistan. The heavy decrease in Bihar and Orissa in 1932 continues that of 1931. With the exception of Talcher which showed a substantial increase of 111,274 tons (from 142,312 tons to 253,586 tons), this decrease was shared by all the fields, the most important falls being 1,203,754 tons in Jharia, 307,624 tons in Bokaro, 129,890 tons in Giridih, 111,706 tons in Raniganj, and 52,112 tons in Karanpura. In Central India there was a further decrease in the output from Umaria of 9,028 tons, which was much more than offset by a further substantial increase of 22,588 tons from the Sohagpur field. In the Central Provinces there was another large increase amounting to 81,802 tons in the output from the Pench Valley, whilst the output of Korea State, which showed an initial production of 3,517 tons in 1930, rising to 31,351 tons in 1931, amounted to 113,858 tons in 1932, representing the very large increase of 82,507 tons. On the other hand, Ballarpur showed a small decrease (5,604 tons). In Hyderabad, the Singareni field was responsible for a decrease of over 110,000 tons, and Sasti

for an increase of nearly 8,000 tons: in addition, there was an initial separately reported output of 126,471 tons from the Tandur coalfield.

In 1929 the statistical position at the end of the year showed a very great improvement in spite of the increase in the total output, stocks in the six provinces of Assam, Baluchistan, Bengal, Bihar and Orissa, the Central Provinces, and the Punjab, for which such figures are available, showing a total reduction of 781,477 tons. In 1930 the smaller increase in production was not accompanied by another improvement in the statistical position, but by a slight worsening, namely an increase of stock amounting to 141,766 tons. In 1931, in spite of a large fall in production of over 2,000,000 tons, the position deteriorated still further with an increase of stocks of 428,334 tons, and in 1932 this deterioration continued, so that in spite of a decreased output of over 1½ million tons stocks increased by 250,629 tons. The data are given in the following table:—

| Year. | Opening stock. | Closing stock. | Reduction during year. |
|---|---|---|---|
| | Tons. | Tons. | Tons. |
| 1927 . . . . . . . | 2,161,806 | 1,721,288 | *440,518* |
| 1928 . . . . . . . | 1,721,288 | 1,625,717 | *95,571* |
| 1929 . . . . . . . | 1,625,717 | 844,240 | *781,477* |
| 1930 . . . . . . . | 844,240 | 986,006 | (*a*) **141,766** |
| 1931 . . . . . . . | 986,006 | 1,414,340 | (*a*) **428,334** |
| 1932 . . . . . . . | 1,414,340 | 1,664,969 | (*a*) **250,629** |

(*a*) Increase of stocks.

The decreased output of 7·2 per cent. was accompanied by a decrease of 16·4 per cent. in the total value of the coal produced in India from Rs. 8,26,98,364 (£6,125,804) in 1931 to Rs. 6,80,96,604 (£5,120,045) in 1932.

There was a decrease of Re. 0-6-10 in the pit's mouth value per ton of coal for India as a whole, namely from Rs. 3-12-11 to Rs. 3-6-1, a very serious fall at this low level of prices. With two exceptions a fall was recorded in every province. In the two great coal provinces, Bihar and Orissa and Bengal, the value fell by Re. 0-6-7 and Re. 0-9-1 respectively. In other provinces, the price fell in Assam by Re. 0-7-6; in the Central Provinces by Re. 0-3-9; in Baluchistan by Re. 0-3-6; in Hyderabad by Re. 0-1-11; and in Central India by Re. 0-1-5. On the other hand the price rose in the Punjab by Re. 0-6-10; and in Rajputana by Re. 0-2-4.

**TABLE 5.**—*Provincial production of Coal during the years 1931 and 1932.*

| Province. | 1931. | 1932. | Increase. | Decrease. |
|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Tons. |
| Assam | 275,021 | 210,035 | .. | 64,986 |
| Baluchistan | 16,554 | 18,928 | 2,374 | .. |
| Bengal | 5,810,184 | 5,782,603 | .. | 27,581 |
| Bihar and Orissa | 13,532,794 | 11,847,216 | .. | 1,685,578 |
| Central India | 226,928 | 240,488 | 13,560 | .. |
| Central Provinces | 1,004,391 | 1,163,096 | 158,705 | .. |
| Hyderabad | 757,575 | 781,121 | 23,546 | .. |
| Punjab | 54,840 | 72,857 | 18,017 | .. |
| Rajputana | 38,148 | 37,043 | .. | 1,105 |
| TOTAL | **21,716,435** | **20,153,387** | *216,202* | *1,779,250* |

**TABLE 6.**—*Value of Coal produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Value (£1 = Rs. 13·5). | | Value per ton. | Value (£1 = Rs. 13·3). | | Value per ton. |
| | Rs. | £ | Rs. A. P. | Rs. | £ | Rs. A. P. |
| Assam | 31,02,094 | 229,785 | 11 4 5 | 22,70,039 | 170,680 | 10 12 11 |
| Baluchistan | 1,34,296 | 9,948 | 8 1 9 | 1,49,385 | 11,232 | 7 14 3 |
| Bengal | 2,21,68,189 | 1,642,088 | 3 13 1 | 1,88,07,330 | 1,414,085 | 3 4 0 |
| Bihar and Orissa | 4,87,78,145 | 3,613,196 | 3 9 8 | 3,78,23,891 | 2,843,901 | 3 3 1 |
| Central India | 9,70,329 | 71,876 | 4 4 5 | 10,06,944 | 75,710 | 4 3 0 |
| Central Provinces | 40,68,974 | 301,405 | 4 0 10 | 44,41,896 | 333,977 | 3 13 1 |
| Hyderabad (*a*) | 30,61,779 | 226,798 | 4 0 8 | 30,63,495 | 230,338 | 3 14 9 |
| Punjab | 2,65,067 | 19,635 | 4 13 4 | 3,83,155 | 28,809 | 5 4 2 |
| Rajputana | 1,49,491 | 11,073 | 3 14 8 | 1,50,469 | 11,313 | 4 1 0 |
| TOTAL | **8,26,98,364** | **6,125,804** | .. | **6,80,96,604** | **5,120,045** | .. |
| Average | .. | .. | 3 12 11 | .. | .. | 3 6 1 |

(*a*) Estimated.

TABLE 7.—*Origin of Indian Coal raised during the years 1931 and 1932.*

| — | Average of last five years. | 1931. | 1932. |
|---|---|---|---|
| | Tons. | Tons. | Tons. |
| Gondwana coalfields . . . . | 22,298,726 | 21,331,872 | 19,814,524 |
| Tertiary coalfields . . . . | 413,959 | 384,563 | 338,863 |
| TOTAL . | **22,712,685** | **21,716,435** | **20,153,387** |

TABLE 8.—*Output of Gondwana Coalfields for the years 1931 and 1932.*

| — | 1931. Tons. | 1931. Per cent. of Indian total. | 1932. Tons. | 1932. Per cent. of Indian total. |
|---|---|---|---|---|
| *Bengal, Bihar and Orissa*— | | | | |
| Bokaro . . . . | 1,656,597 | 7·63 | 1,348,973 | 6·69 |
| Daltonganj . . . | 411 | 0·00 | .. | .. |
| Giridih . . . . | 713,133 | 3·28 | 583,243 | 2·90 |
| Jainti . . . . | 50,178 | 0·23 | 43,163 | 0·21 |
| Jharia . . . . | 9,755,037 | 44·92 | 8,551,283 | 42·43 |
| Karanpura . . . | 461,678 | 2·13 | 409,566 | 2·03 |
| Rajmahal Hills . . | 1,699 | 0·01 | 1,500 | 0·01 |
| Rampur (Raigarh-Hingir) | 31,220 | 0·14 | 19,498 | 0·10 |
| Raniganj . . . | 6,530,713 | 30·07 | 6,419,007 | 31·85 |
| Talcher . . . | 142,312 | 0·66 | 253,586 | 1·26 |
| *Central India*— | | | | |
| Sohagpur . . . | 143,607 | 0·66 | 166,195 | 0·82 |
| Umaria . . . | 83,321 | 0·38 | 74,293 | 0·37 |
| *Central Provinces*— | | | | |
| Ballarpur . . . | 223,025 | 1·03 | 217,421 | 1·08 |
| Korea . . . . | 31,351 | 0·14 | 113,858 | 0·56 |
| Pench Valley . . | 750,015 | 3·45 | 831,817 | 4·13 |
| *Hyderabad*— | | | | |
| Sasti . . . . | 53,417 | 0·25 | 61,184 | 0·30 |
| Singareni . . . | (*a*)704,158 | 3·24 | 593,466 | 2·95 |
| Tandur . . . . | .. | .. | 126,471 | 0·63 |
| TOTAL . | **21,331,872** | *98·22* | **19,814,524** | *98·32* |

(*a*) Includes production from Tandur coalfield, not separately reported.

TABLE 9.—*Output of Tertiary Coalfields for the years 1931 and 1932.*

| — | 1931. Tons. | 1931. Per cent. of Indian total. | 1932. Tons. | 1932. Per cent. of Indian total. |
|---|---|---|---|---|
| *Assam*— | | | | |
| Khasi and Jaintia Hills | 743 | 1·27 | 1,233 | 1·04 |
| Makum | 239,315 | | 170,399 | |
| Naga Hills | 34,963 | | 38,403 | |
| *Baluchistan*— | | | | |
| Khost | 3,821 | 0·08 | 5,297 | 0·10 |
| Sor Range, Mach, Kalat | 12,733 | | 13,631 | |
| *Punjab*— | | | | |
| Jhelum | 27,386 | 0·25 | 32,527 | 0·36 |
| Mianwali | 22,831 | | 30,792 | |
| Shahpur | 4,623 | | 9,538 | |
| *Rajputana*— | | | | |
| Bikaner | 38,148 | 0·18 | 37,043 | 0·18 |
| TOTAL | **384,563** | *1·78* | **338,863** | *1·68* |

The development of an iron and steel industry in India on modern lines has led to the erection of several plants for the manufacture of hard coke of metallurgical quality, and it has therefore become a matter of general interest to know the proportion of the total annual output of coal in India that is utilised in the manufacture of hard coke.

The figures for 1931 and 1932 are shown in the table 10.

TABLE 10.—*Quantity of Hard Coke produced in India in the years 1931 and 1932.*

| — | 1931. | 1932. |
|---|---|---|
| | Tons. | Tons. |
| Coal used | 1,754,469 | 1,635,972 |
| Hard coke manufactured | 1,309,308 | 1,214,526 |
| *Percentage recovery* | *74·74* | *74·72* |
| *Source of coal used*— | | |
| Jharia field | 1,687,681 | 1,585,733 |
| Giridih field | 33,209 | 32,724 |
| Bokaro field | 21,123 | 4,637 |
| Raniganj field | 12,456 | 12,878 |
| TOTAL | **1,754,469** | **1,635,972** |
| *Coal used for coking by*— | | |
| Three iron and steel companies | 1,341,055 | 1,322,969 |
| Others | 413,414 | 313,003 |

In reversal of 1930 and 1931, the export statistics for coal during 1932 show an increase, amounting to about 78,500 tons (*see* Table 11). Exports to Hongkong increased greatly from 89,127 tons in 1931 to 218,638 tons in 1932. As the exports to Ceylon fell from 281,684 tons in 1931 to 190,237 tons in 1932, Hongkong, for the first time, became the leading importer of Indian coal. Exports to the Straits Settlements (including Labuan) decreased by some 16,000 tons, whilst those to the Philippine Islands and Guam showed an increase of about 7,000 tons. The United Kingdom took 32,699 tons against 10,785 tons in the previous year and other countries absorbed about 28,000 tons more. The export of coke decreased by 332 tons.

TABLE 11.—*Exports to foreign ports of Indian Coal and Coke during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13-5). | | Quantity. | Value (£1 = Rs. 13-3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| Ceylon | 281,684 | 34,20,682 | 253,384 | 190,237 | 22,63,725 | 170,205 |
| Hongkong | 89,127 | 8,16,628 | 60,491 | 218,638 | 17,34,610 | 130,422 |
| Philippine Islands and Guam | 21,770 | 1,80,679 | 13,384 | 29,043 | 2,53,326 | 19,047 |
| Straits Settlements (including Labuan). | 29,822 | 3,08,992 | 22,888 | 13,058 | 1,33,352 | 10,027 |
| United Kingdom | 10,785 | 94,062 | 6,967 | 32,699 | 3,72,953 | 28,041 |
| Other countries | 6,275 | 66,245 | 4,907 | 33,854 | 3,79,943 | 28,567 |
| TOTAL | 438,963 | 48,87,288 | 362,021 | 517,529 | 51,37,909 | 386,309 |
| Coke | 2,286 | 45,437 | 3,366 | 1,954 | 38,955 | 2,929 |
| **Total of coal and coke** | **441,249** | *49,32,725* | *365,387* | **519,483** | *51,76,864* | *389,238* |

The following table gives the amounts of different grades of coal exported during 1931 and 1932 under the Indian Coal Grading Board's scheme (including sea-borne coal for railways in Southern India, for which no grade shipment certificates were issued by the Coal Grading Board) and shows an increase of 40,531 tons in the present year, the difference between the total amounts so exported (2,209,085 tons in 1932) and the total exports of Indian coal to foreign ports given in Table 11 (517,529 tons in 1932) being the amount of coal exported to Indian ports.

TABLE 12.—*Exports of Coal under Grading Board Certificates during the years 1931 and 1932.*

| — | 1931. | 1932. |
|---|---|---|
| | Tons. | Tons. |
| Selected grade | 1,980,021 | 1,987,808 |
| Grade I | 185,067 | 211,534 |
| Grade II | 2,271 | 6,120 |
| Mixed grade | 1,195 | 3,623 |
| TOTAL | **2,168,554** | **2,209,085** |

Imports of coal and coke showed during 1932 another substantial fall, namely from 88,035 tons in 1931 to 47,544 tons in 1932; 13,912 tons of the latter consisted of coke (*see* Table 13). This fall is due mainly to a decrease of some 30,000 tons from South Africa, and of 9,000 tons from the United Kingdom. The total imports are now about a tenth of those of the pre-war quinquennium and Table 14 comparing pre-war imports and exports with the figures from 1926 to 1932, shows that the depression in the Indian coal industry, which was accentuated in 1932, cannot be ascribed to the competitive effect of foreign imported coal. The average surplus of exports over imports during the years 1926 to 1932 was, in fact, greater than the surplus during the pre-war quinquennium.

TABLE 13.—*Imports of Coal and Coke during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13-5) | | Quantity. | Value (£1 = Rs. 13-3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *From—* | | | | | | |
| Australia | 3,400 | 74,590 | 5,525 | 4,070 | 93,760 | 7,050 |
| United Kingdom | 27,920 | 6,27,540 | 46,484 | 18,505 | 4,05,487 | 30,488 |
| Union of South Africa | 39,441 | 6,74,025 | 49,928 | 8,620 | 1,20,350 | 9,049 |
| Other countries | 5,325 | 84,422 | 6,253 | 2,437 | 40,492 | 3,044 |
| TOTAL | 76,086 | 14,60,577 | 108,190 | 33,632 | 6,60,089 | 49,631 |
| Coke | 11,949 | 3,23,212 | 23,942 | 13,912 | 3,46,275 | 26,036 |
| **Total of coal and coke** | **88,035** | *17,83,789* | *132,132* | **47,544** | *10,06,364* | *75,667* |

TABLE 14.—*Excess of exports over imports of Coal.*

| — | Exports. | Imports. | Excess of exports over imports. |
| --- | --- | --- | --- |
| | Tons. | Tons. | Tons. |
| Average for 1909-13 . . . . | 814,475 | 466,162 | 348,313 |
| 1926 . . . . . . . | 617,563 | 193,908 | 423,655 |
| 1927 . . . . . . . | 576,167 | 243,603 | 332,564 |
| 1928 . . . . . . . | 626,343 | 210,186 | 416,157 |
| 1929 . . . . . . . | 726,610 | 218,560 | 508,050 |
| 1930 . . . . . . . | 461,188 | 217,029 | 244,159 |
| 1931 . . . . . . . | 441,249 | 88,035 | 353,214 |
| 1932 . . . . . . . | 519,483 | 47,544 | 471,939 |

The average number of persons employed in the coalfields during the year showed a smaller decrease (4·4 per cent.) than the decrease in production (7·2 per cent.). The average output per person employed, therefore, showed a decrease to 121·7 tons in contrast with the advances up to 1930, which have been 110·5 tons for 1925, rising to 113·1 tons for 1926, 122·3 tons for 1927, 125·5 tons for 1928, 130·4 tons for 1929, and 129·1 tons for 1930, with a decrease to 125·4 tons in 1931. Except for the last five years, however, the figure for the year under review is still higher than those previously recorded; these higher figures are due, partly to an increased use of mechanical coal-cutters, and partly to concentration of work. During the past few years a large number of collieries have been shut down and the labour absorbed in the remainder; this concentration permits of a proportional reduction of the supervising staff, resulting in a larger tonnage per head. There was a decrease in the number of deaths by accident from 196 in 1931 to 164; the latter figure is much better than the annual average for the quinquennium 1919-1923, which was 274, and also below the annual average for the quinquennium 1924-1928, which was 218. The death rate was 1·0 per thousand persons employed in 1932, a little less than the figure for the previous year (1·1); the average figure for the period 1919-1923 was 1·36, and for the period 1924-1928 was 1·16.

TABLE 15.—*Average number of persons employed daily in the Indian Coalfields during the years 1931 and 1932.*

| —— | 1931. | 1932. | Output per person employed in tons. | Number of deaths by accident. | Death rate per 1,000 persons employed. |
|---|---|---|---|---|---|
| Assam | 3,533 | 2,275 | 92·3 | 7 | 3·1 |
| Baluchistan | 261 | 264 | 71·7 | .. | .. |
| Bengal | 44,642 | 43,423 | 133·2 | 44 | 1·0 |
| Bihar and Orissa | 102,115 | 95,082 | 124·6 | 86 | 0·9 |
| Central India | 1,851 | 2,108 | 114·1 | 2 | 0·9 |
| Central Provinces | 9,138 | 10,221 | 113·8 | 13 | 1·3 |
| Hyderabad | 10,501 | 10,753 | 72·6 | 11 | 1·0 |
| Punjab | 985 | 1,315 | 55·4 | 1 | 0·8 |
| Rajputana | 149 | 126 | 294·0 | .. | .. |
| TOTAL | **173,175** | **165,567** | .. | **164** | .. |
| *Average* | .. | .. | *121·7* | .. | *1·0* |

## Cobalt (*see* Nickel).

## Copper.

The progress of work at the Mosaboni Mine of the Indian Copper Corporation, Ltd., in the Singhbhum district, and on the milling and smelting plant at Maubhandar, near Ghatsila, Bengal Nagpur Railway, has been noticed in previous reviews. Operations commenced on a revenue basis on January 1st, 1929. During that year the ore produced amounted to 76,831 long tons valued at Rs. 14,58,746 (£108,862). Of this 75,174 short tons were treated in the mill and smelter, with the production of 1,635 long tons of refined copper ingots and slabs. The copper was sold entirely in India at an average price of Rs. 1,200 per long ton. In 1930 the output increased to 123,749 long tons of copper-ore valued at Rs. 24,35,571 (£180,413). Of this 134,162 short tons were treated in the mill and smelter and 1,625 short tons sent direct to the smelter with the production of 2,974 long tons of refined copper of which 2,157 tons were sold in the Indian market and 540 tons were consumed in the new rolling mill, which was completed in July 1930, with the production of 712 tons of yellow metal (brass) sheet, which found a ready market in Calcutta.

In 1931 the mine output was 153,636 long tons of copper-ore valued at Rs. 22,71,940 (£168,292). 161,563 short tons of ore were treated for a production of 4,069 long tons of refined copper. 1,668 tons of this were sold in the Indian market at an average price of Rs. 673 per ton. In addition there was a production of 3,637 tons of yellow metal, the average selling price in India being Rs. 719 per ton.

Operations continued uninterruptedly during the year 1932 at the Mosaboni Mine and at the works site at Maubhandar. The mine output increased to 175,010 long tons of copper-ore valued at Rs. 25,09,080 (£188,652). 185,894 short tons of ore were treated in the mill and the production of refined copper amounted to 4,443 long tons. 3,441 tons were consumed in the rolling mill and 1,312 tons were sold in the Indian market at an average price of Rs. 689 per ton. Operations in the rolling mill resulted in the production of 5,440 long tons of yellow metal, of which 4,830 were sold in India at an average price of Rs. 657 per ton.

The total ore reserves at the close of the year 1932 amounted to 700,466 short tons with an average assay value of 3·053 per cent. of copper.

There was a considerable decrease in the production of copper-matte at the Namtu smelting plant of the Burma Corporation, Limited, from 13,437 tons valued at Rs. 32,25,003 (£238,889) in 1931, to 9,729 tons valued at Rs. 19,81,499 (£148,985) and averaging 44·32 per cent. of copper, 26·36 per cent. of lead, and 83·73 ozs. of silver to the ton.

In addition 365 tons of copper-ore valued at Rs. 6,900 (£519) were produced in the Nellore district, Madras.

## Diamonds.

The production of diamonds in Central India rose from 639 carats valued at Rs. 34,683 (£2,569) in 1931, to 1254·1 carats valued at Rs. 72,189 (£5,428) in 1932. Of this latter production 1152·1 carats were produced in Panna State and the remainder in Charkhari, Ajaigarh, and Bijawar.

## Gold.

There was a trivial fall in the total Indian gold production from 330,488·8 ozs. valued at Rs. 2,08,01,943 (£1,540,885) in 1931,

to 329,681·7 ozs. valued at Rs. 2,53,51,438 (£1,906,123) in 1932. There was again a small production from Singhbhum, and as in the previous year small outputs from Burma, the Punjab and the United Provinces. But these figures are, of course, quite insignificant compared with the output of Kolar which makes up 99·97 per cent. of the Indian total. The considerable increase in the value of the production is due to 1932 being the first full year since Britain and India abandoned the gold standard in September, 1931, with consequent appreciation in price of gold, against sterling or rupees. As a result of this appreciation in the price of gold, 9,666,122 ozs. of gold reckoned in terms of fine gold were exported during 1932. The value was Rs. 75,87,52,203 (£57,049,038).

Of the five mines that were producing gold on the Kolar goldfield, the Balaghat Gold Mine was, owing to unfavourable development in depth, sold on the 1st May 1932, to the Nundydroog Mines, Ltd., the latter company undertaking to mine and treat the ore reserves remaining in the Balaghat Mine. The Champion Reef and the Ooregum Mines, the two deepest on the field, reached vertical depths of 7,330 ft. and 7,149 ft. respectively below field datum on the 31st December, 1932. The developments in depth have disclosed the continuity of the reef, and shoots of payable ore of small dimensions have been opened up. In these deep levels the dip of the reef is almost vertical. The ore is not refractory and, yields its gold to blanket concentration and cyaniding; 'all-sliming' practice is becoming general. The concentrates are pan- or plate-amalgamated. The rock temperature at the 76th level Champion Reef Mine was 126·8° F. and at the 76th level Ooregum Mine was 124·2°F. Owing to the great depths of these mines and the consequent high temperatures, the maintenance of adequate ventilation at the working places continues to be an extremely difficult problem. It has been partly solved by sinking deep smooth-lined vertical or eliptical shafts and by an extensive use of large electrically-driven fans in the course of the main air currents. The shafts and winzes in the lower levels are all brick- or concrete-lined and as such assist the free movement of air by reducing friction to a minimum. In spite of the more rigid forms of support such as packs of masonry and concrete, and sand filling, rockbursts continue to occur causing considerable damage to person and property.

The average number of persons employed on the Kolar Gold Field during 1932 was 18,816.

TABLE 16.—*Quantity and value of Gold* produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | | Labour in 1932. |
|---|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | | |
| | Ozs. | Rs. | £ | Ozs. | Rs. | £ | |
| *Bihar and Orissa*— | | | | | | | |
| Singhbhum . | .. | .. | .. | 50·0 | 3,650 | 274 | 4 |
| *Burma*— | | | | | | | |
| Katha . . | 18·8 | 1,005 | 75 | 18·2 | 950 | 72 | 2 |
| Upper Chindwin. | 18·0 | 960 | 71 | 28·4 | 2,649 | 199 | |
| *Mysore* . . | 330,437·5 | 2,07,99,131 | 1,540,676 | 329,574·9 | 2,53,43,443 | 1,905,522 | 18,816 |
| *Punjab* . . | 10·0 | 583 | 43 | 6·6 | 480 | 36 | 47 |
| *United Provinces* | 4·5 | 264 | 20 | 3·6 | 266 | 20 | 23 |
| TOTAL . | 330,488·8 | *2,08,01,943* | *1,540,885* | 329,681·7 | *2,53,51,438* | *1,906,123* | 18,892 |

* Fine ounces in the case of Mysore.

## Ilmenite.

There was a large increase in the production of ilmenite in Travancore State from 36,166 tons valued at £41,991 in 1931, to 50,052·5 tons valued at £58,134 in 1932. This mineral occurs in the monazite sands and, up to a few years ago, was looked upon as a bye-product of the monazite industry. The monazite sands have been worked continuously since 1911, but it was not until 1922 that the export of ilmenite commenced, since when the production of the mineral has expanded almost continuously, so that in both quantity and value the production of ilmenite is now much more important than that of the associated minerals monazite and zircon. This steady increase in the output of ilmenite is due to the demand for its contents of titanium dioxide in the manufacture of titanium paints.

In value in 1932 ilmenite had advanced to the position of sixteenth in the list of India's mineral products.

## Iron.

For some years up to and including 1929 the production of iron-ore in India had been steadily increasing; India is now, in fact, the second largest producer in the British Empire, and yields place

only to the United Kingdom. Her output is of course still completely dwarfed by the production in the United States (over 59 million tons in 1930 and 31 million tons in 1931) and France (48 and 38 million tons in 1930 and 1931, respectively); but her reserves of ore are not much less than three-quarters of the estimated total in the United States, and there is every hope that India will eventually take a much more important place among the world's producers of iron-ore. In 1930, however, the prevailing depression was reflected in a decrease in the Indian output over the previous year of 23·8 per cent. amounting to 578,930 tons, followed by a further fall of 224,742 tons (12·1 per cent.) in 1931. In 1932, however, in spite of the continuance of the depression there was a partial recovery in the production of iron-ore in India of 135,618 tons (8·3 per cent.). It will be seen later, however, that there were further falls in the output of pig-iron and steel. The figures shown against the Keonjhar and Mayurbhanj States in Table 17 represent the production by the United Steel Corporation of Asia, Ltd., and the Tata Iron and Steel Co., Ltd., respectively. Of the total production of 666,874 tons shown against Singhbhum, 528,370 tons were produced by the Tata Iron and Steel Co., Ltd., from their Noamundi mine, and 138,504 tons by the Indian Iron and Steel Co., Ltd., from their mines at Gua. The output of iron-ore in Burma is by the Burma Corporation, Limited, and is used as a flux in lead smelting.

TABLE 17.—*Quantity and value of Iron-ore produced in India during the years, 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons | Rs. | £ | Tons | Rs. | £ |
| *Bihar and Orissa*— | | | | | | |
| Keonjhar | 109,841 | 1,09,841 | 8,136 | 186,173 | 1,86,173 | 13,998 |
| Mayurbhanj | 901,246 | 27,03,738 | 200,277 | 891,193 | 21,33,961 | 160,448 |
| Puri | 9 | 12 | 1 | .. | .. | .. |
| Sambalpur | .. | .. | .. | 7 | 50 | 4 |
| Singhbhum | 588,290 | 12,65,325 | 93,728 | 666,874 | 15,51,217 | 116,633 |
| *Burma*— | | | | | | |
| Northern Shan States | 1,886 | 7,544 | 559 | 6,560 | 26,240 | 1,973 |
| *Central Provinces* | 763 | 2,289 | 170 | 808 | 2,409 | 181 |
| *Madras*— | | | | | | |
| East Godavari | 4,329 | 2,597 | 192 | 4,496 | 4,456 | 335 |
| *Mysore State* | 18,519 | 67,391 | 4,992 | 4,395 | 15,263 | 1,148 |
| TOTAL | 1,625,383 | *41,58,737* | *308,055* | 1,760,501 | *39,19,769* | *294,720* |

In contrast with the preceding year there was a fall in the total output of iron and steel by the Tata Iron and Steel Co. at Jamshedpur. The production of pig-iron fell from 799,545 tons in 1931 to 699,931 tons in 1932, with decreases in the production of steel (including steel rails) from 439,134 tons in 1931 to 430,333 tons in 1932, and of ferro-manganese from 14,366 tons in 1931 to 366 tons in 1932. As in 1931, there was no production of pig-iron by the Bengal Iron Co.; their output of products made from pig-iron in 1932 amounted to 3,371 tons of sleepers and chairs, and 17,266 tons of pipes and other castings, against 28,211 tons and 32,760 tons, respectively, in 1931. The Indian Iron and Steel Co. decreased their production of pig-iron from 243,214 tons in 1931 to 198,700 tons in 1932. The output of pig-iron by the Mysore Iron Works fell from 15,577 tons in 1931 to 14,683 tons in 1932. The total production of pig-iron in India fell from 1,058,336 tons in 1931 to 913,314 tons in 1932 and is shown in Table 18.

TABLE 18.—*Production of Pig-iron in India during the years 1931 and 1932.*

| | 1931. | 1932. |
|---|---|---|
| | Tons. | Tons. |
| The Tata Iron and Steel Company, Limited | 799,545 | 699,931 |
| The Indian Iron and Steel Company, Limited | 243,214 | 198,700 |
| The Mysore Iron Works | 15,577 | 14,683 |
| TOTAL | **1,058,336** | **913,314** |

The total number of indigenous furnaces that were at work in the Central Provinces during the year 1932 for the purpose of smelting iron-ore was 118 against 106 in the previous year; 59 furnaces were operating in the Bilaspur district, 51 in Mandla, 3 in Raipur, 1 in Saugor, 3 in Drug, and none in Jubbulpore.

The decrease in the production of pig-iron in India recorded above was accompanied by a fall in the quantity exported from 318.994 tons in 1931 to 250,137 tons in 1932. Table 19 shows that Japan is still the principal consumer of Indian pig-iron, but the proportion fell from 49 per cent. in 1931 to 41·5 per cent. in 1932, whilst the actual amount fell by 34 per cent. Exports to all other

countries fell substantially except to United Kingdom to which a rise of about 65 per cent. (33,732 tons) took place. The export value per ton of pig-iron varied slightly from Rs. 35·1 (£2·6) in 1931 to Rs. 34·8 (£2·62) in 1932.

The Steel Industry (Protection) Act, 1924, Act No. XIV of 1924, authorised, to companies employing Indians, bounties upon rails and fishplates wholly manufactured in British India from material wholly or mainly produced from Indian iron-ore and complying with specifications approved by the Railway Board, and upon iron or steel railway wagons, a substantial portion of the component parts of which had been manufactured in British India. This Act was repealed by the Act No. III of 1927 and the payment of bounties consequently ceased on the 31st March 1927; the industry is, however, protected to a certain extent by varying tariffs on different classes of imported steel.

TABLE 19. *Exports of Pig-iron from India during the years 1931 and 1932.*

| —— | 1931 | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity | Value (£1 = Rs 13·5) | | Quantity. | Value (£1 = Rs 13·3). | |
| | Tons | Rs | £ | Tons | Rs. | £ |
| To— | | | | | | |
| China | 17,746 | 6,24,445 | 46,255 | 14,417 | 5,06,948 | 38,116 |
| Germany | 14,382 | 5,01,671 | 37,161 | 8,348 | 2,91,223 | 21,896 |
| Japan | 157,116 | 55,32,337 | 409,803 | 103,724 | 35,81,496 | 269,285 |
| United Kingdom | 51,600 | 17,92,440 | 132,773 | 85,332 | 29,97,467 | 225,374 |
| United States of America | 60,121 | 21,15,522 | 156,705 | 26,978 | 9,45,945 | 71,124 |
| Other Countries | 18,079 | 6,37,052 | 47,189 | 11,388 | 3,92,056 | 29,478 |
| TOTAL | **318,994** | *1,12,03,467* | *829,886* | **250,187** | *87,15,135* | *655,273* |

## Jadeite.

There was a small increase in the output of jadeite, which rose from 2,765 cwts. valued at Rs. 7,72,860 (£57,249) in 1931, to 3,025·8 cwts. valued at Rs. 3,26,373 (£24,539) in 1932. The output figures are liable to be incomplete, and a more correct idea of the extent of the Burmese jadeite industry, especially of values, is sometimes obtainable from the export figures. Exports by sea rose from 2,500 cwts. valued at Rs. 3,52,264 (£26,094) in 1931-32 to 3,654 cwts. valued at Rs. 3,77,178 (£28,359) in 1932. These shipments were entirely from Burma. Exports from Burma by land during the year amounted to 110 cwts. only.

## Lead.

The production of lead-ore at the Burma Corporation's Bawdwin mines in Burma decreased further from 397,679 tons in 1931 to 372,586 tons in 1932, and the total amount of metal extracted decreased from 74,785 tons of lead (including 1,505 tons antimonial lead) valued at Rs. 1,28,88,270 (£954,687) in 1931, to 71,202 tons of lead (including 642 tons of antimonial lead) valued at Rs. 1,09,95,587 (£826,736) in 1932. The quantity of silver extracted from the Bawdwin ores rose slightly from 5,900,400 ozs. valued at Rs. 51,97,367 (£384,990) in 1931, to 5,998,956 ozs. valued at Rs. 62,32,915 (£468,640) in 1932. The value of the lead per ton fell from Rs. 172·3 (£12·8) to Rs. 154·5 (£11·6), whilst the value of the silver rose from Rs. 0-14-1 (15·64*d.*) to Re. 1-0-7 (18·75*d.*) in the year under review. The ore reserves in the Bawdwin mine, as calculated at the end of June, 1932, totalled 4,126,179 tons, against 4,233,120 tons at the end of June, 1931, with an average composition of 25·4 per cent. of lead, 15·6 per cent. of zinc, 0·68 per cent. of copper, and 19·7 ozs. of silver per ton of lead. Included in this reserve are 37,000 tons of copper-ore. During the year development work in the Meingtha section, discovered in 1930, continued to yield satisfactory results.

## Magnesite.

The output of magnesite from Salem district, Madras, and Mysore State, showed a great recovery towards its 1930 amount. The total increase amounted to 8,531 tons, accompanied by an increase in value of Rs. 45,407 (£3,444).

TABLE 20.—*Quantity and value of Magnesite produced in India, during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1=Rs. 13·5). | | Quantity. | Value (£1=Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Madras*— | | | | | | |
| Salem . . | 4,978 | 21,540 | 1,596 | 13,492 | 64,482 | 4,848 |
| *Mysore State* . | 355 | 5,808 | 430 | 372 | 8,273 | 622 |
| TOTAL . | **5,333** | *27,348* | *2,026* | **13,864** | *72,755* | *5,470* |

## Manganese.

Before the year 1926, the record production of manganese-ore in India took place in 1907, when 902,291 tons were raised. In 1926, the output rose to 1,014,928 tons, valued at £2,463,491 f.o.b. Indian ports; the rise in output was, however, accompanied by a decrease in value. In 1927 the production rose to the highest figure yet recorded, 1,129,353 tons, accompanied by a rise in value to the peak figure of £2,703,068 f.o.b. Indian ports. During the year 1928, the upward tendency was not maintained, the output falling to 978,449 tons valued at £2,198,895 f.o.b. Indian ports. In 1929, the output rose again slightly to 994,279 tons, but the value fell heavily to £1,571,030. In 1930 the output fell substantially to 829,946 tons with a heavy fall in value to £1,200,236. In 1931 a still more serious fall took place, to 537,844 tons with a value of £726,954. This has been followed by a disastrous fall in 1932 to 212,604 with a value of £140,022. This is the smallest quantity and value reported since 1904, when the output was 150,190 tons valued at £137,933. In 1905 the output was 247,427 tons valued at £223,432, since when the smallest production was 450,416 tons in 1915 valued at £929,546; whilst the smallest value was in 1909 when a production of 644,660 tons was valued at £603,908. The full magnitude of this catastrophe to the Indian manganese industry is perhaps best realised from the fact that whilst the quantity of the production in 1932 was a little over one-fifth of that of the peak year of 1927, the value was less than one nineteenth of the value of the 1927 production. In fact in none of the major Indian mineral industries have the effects of the slump been so seriously felt as in the manganese industry.

The decrease of 1932, totalling 325,575 tons, was distributed over all producing districts, except Keonjhar State which showed an increase of some 5,000 tons, Vizagapatam district with an increase of some 2,700 tons, and North Kanara with a trivial output against none in the previous year. Production ceased from the Panch Mahals, Belgaum, and Bellary. In the Central Provinces the production fell from 302,344 tons in 1931 to 77,186 tons in 1932, which is the smallest output since 1901, in the infancy of the industry in the Central Provinces, when the output was 44,428 tons. During the year the majority of mines in the Central Provinces were closed including several in mines that had never been closed since the commencement of work in 1900 and 1901.

In 1924, first-grade ore, c.i.f. United Kingdom ports, fetched an average price of 22·9*d*. per unit, in 1925 this price fell to 21·5*d*., in 1926 to 18·4*d*., in 1927 to 18·1*d*., in 1928 to 17·0*d*., with a heavy fall in 1929 to an average price of 14·0*d*. per unit. In 1930 the price fell to 13·1*d*. per unit, that is to the post-war lower governing price of manganese,[1] with an index figure of cost of supplies and services of 1·45, in 1931 to 11·8*d*. and in 1932 to 9·6*d*. per unit. This continued fall in the price of manganese-ore from 1924 to 1931 is to be correlated with the fact that from 1924 to 1927 the rate of increase of the world's production of manganese-ore was much greater than the rate of increase in the world's production of pig-iron and steel. And although there was a fall in the world's output of manganese-ore in 1928, there was a very large increase in 1929, greater than was justified by the increased production of iron and steel in that year, and it is evident that the world's available supplies of manganese-ore are now much in excess of requirements. Russia, by non-economic methods of exploitation and finance, is able to place large quantities of ore on the market at a price well below both the critical figure of 13·1*d*. referred to above and also below any revised figure allowing for the fall in index figures. During 1932 the price of Russian ore fell from 9 to 9½*d*. c.i.f. at the beginning of the year to 8½ to 9*d*. c.i.f. per unit at the end of the year, a figure with which India cannot compete without a return to pre-war railway freights and pre-war labour charges, The Indian trade has accordingly suffered severely. The large deposits of high-grade manganese-ore discovered near Postmasburg in South Africa are also being developed, and it may be anticipated that eventually South Africa will secure a substantial portion of the world's market, although production from this field was suspended during 1932. It is not surprising, therefore, that in spite of the apparent prosperity of the Indian manganese industry in 1929 and 1930 as judged from figures of production and export, yet by 1930 the industry as a whole had arrived at a stage of relative depression, causing many operators to cease work. Added to increased available supplies there has been in 1931 and 1932 the disastrous decline in the activities of the iron and steel industry of the world, illustrated by a decline from the peak figure of 122 million tons of steel in 1929 to about 70 million tons in 1931 and only 50 million tons in 1932.*

[1] See *Rec. Geol. Surv. Ind.*, Vol. LXIV, p. 192 (1930).
* *Mining Journal*, 11th February, 1933, p. 14.

The present chief sources of production of manganese-ore are now India, Russia, the Gold Coast, South Africa, and Brazil, whilst substantial supplies of ore are forthcoming from Egypt and Czechoslovakia.

There is a steady consumption of manganese-ore at the works of the three principal Indian iron and steel companies, not only for use in the steel furnaces of the Tata Iron and Steel Company, and for the manufacture of ferro-manganese, but also for addition to the blast-furnace charge in the manufacture of pig-iron. The consumption of manganese-ore by the Indian iron and steel industry in the year under review amounted to 19,647 tons, against 53,037 tons in 1931.

TABLE 21.—*Quantity and value of Manganese-ore produced in India during the years 1931 and 1932.*

| — | 1931. | | 1932. | |
|---|---|---|---|---|
| | Quantity. | Value f.o.b. at Indian ports. | Quantity. | Value f.o.b. at Indian ports. |
| | Tons. | £ | Tons. | £ |
| *Bihar and Orissa—* | | | | |
| Keonjhar State | 39,665 | 40,987 | 44,908 | 23,296 |
| Singhbhum | 7,938 | 12,370 | 2,272 | 2,300 |
| *Bombay—* | | | | |
| Belgaum | 474 | 739 | .. | .. |
| North Kanara | .. | .. | 612 | 620 |
| Panch Mahals | 31,184 | 48,595 | .. | .. |
| *Central Provinces—* | | | | |
| Balaghat | 119,466 | 198,115 | 36,762 | 40,132 |
| Bhandara | 82,999 | 137,640 | 10,918 | 11,919 |
| Chhindwara | 16,404 | 27,203 | 10,041 | 10,961 |
| Nagpur | 83,475 | 138,429 | 19,465 | 21,249 |
| *Madras—* | | | | |
| Bellary | 44 | 34 | .. | .. |
| Sandur State | 149,833 | 117,369 | 79,023 | 26,176 |
| Vizagapatam | 5,389 | 4,670 | 8,049 | 3,169 |
| *Mysore—* | | | | |
| Chitaldrug | 425 | 351 | 219 | 79 |
| Shimoga | 548 | 452 | 335 | 121 |
| TOTAL | **537,844** | *726,954* | **212,604** | *140,022* |

Exports, including the quantities exported from Mormugao in Portuguese India, fell from 417,957 tons in 1931 to 301,252 tons in 1932. Table 23 shows the distribution of manganese-ore exported from British Indian ports (excluding Mormugao) during 1931 and 1932, from which it will be seen that as in 1931, France with a small decrease of some 6,500 tons, was the chief importer of Indian manganese-ore. The second place as importer was held by the United Kingdom with a decrease of some 7,000 tons. Belgium again showed a substantial decrease amounting to some 16,000 tons, and the Netherlands of 1,500 tons, whilst the exports to the United States of America, one of India's principal markets for manganese-ore, ceased completely. In contrast to the above decreases other countries increased their takings by about 19,000 tons.

TABLE 22.—*Exports of Manganese-ore during 1931 and 1932 according to ports of Shipment.*

| —— | 1931. | 1932. |
|---|---|---|
| | Tons. | Tons. |
| Bombay | 88,681 | 58,145 |
| Calcutta | 153,535 | 131,399 |
| Madras | 4,331 | 3,200 |
| Mormugao (Portuguese India) | 171,410 | 108,508 |
| TOTAL | 417,957 | 301,252 |

TABLE 23.—*Export of Manganese-ore from British Indian ports during the years 1931 and 1932.*

| —— | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1=Rs. 13-5). | | Quantity. | Value (£1=Rs. 13-3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| To— United Kingdom | 61,818 | 17,92,689 | 132,788 | 54,397 | 15,45,175 | 116,179 |
| Germany | 4,240 | 1,28,779 | 9,539 | 1,056 | 19,874 | 1,494 |
| Netherlands | 3,500 | 1,29,375 | 9,583 | 2,000 | 50,000 | 3,759 |
| Belgium | 41,500 | 12,77,475 | 94,628 | 25,402 | 7,39,645 | 55,613 |
| France | 90,009 | 20,43,310 | 151,356 | 83,521 | 19,96,799 | 150,135 |
| United States of America. | 38,970 | 11,70,800 | 86,726 | .. | .. | .. |
| Other Countries | 7,015 | 1,77,299 | 13,133 | 26,368 | 5,74,628 | 43,205 |
| TOTAL | 246,547 | *67,19,677* | *497,753* | 192,744 | *49,26,116* | *370,385* |

## Mica.

There was a small fall in the declared production of mica from 38,963 cwts. valued at Rs. 20,37,634 (£150,935) in 1931, to 32,713 cwts. valued at Rs. 14,35,401 (£107,925) in 1932. As has been frequently pointed out, the output figures are incomplete, and a more accurate idea of the size of the industry is to be obtained from the export figures. In the years 1926 and 1927 the export figure was approximately double the reported production figure, whilst in the years 1928 and 1929 the quantity exported was more than double the reported production. In 1930 the recorded exports were, however, only some 57 per cent. in excess of the reported production, in 1931 only 36 per cent., and in 1932 only 43 per cent. in excess. This may mean that the Act referred to in the third paragraph is now beginning to produce a definite effect. This will be conclusively proved only by statistics over a period of years.

The United States of America and the United Kingdom, which are the principal importers of Indian mica, absorbed respectively 23·4 per cent. and 43·2 per cent. during 1931, and 24·0 per cent. and 47·6 per cent. during 1932. Germany took 7·2 per cent. and 10·6 per cent. respectively, of the total quantities exported during the years 1931 and 1932. The average value of the exported mica decreased from Rs. 78·3 (£5·8) per cwt. in 1931 to Rs. 71·2 (£5·4) per cwt. in 1932. The exports fell from 52,966 cwts. valued at Rs. 41,48,768 (£307,316) in 1931, to 47,021 cwts. valued at Rs. 33,48,943 (£251,800) in 1932. This is the lowest total value recorded since 1915-16, when the value of the mica exports was £208,496.

The difference between exports and productions is generally attributed to theft from the mines. If this be the only explanation we must assume that during the three years prior to 1930 there has been as much mica stolen as won by honest means. Early in 1928 a bill was introduced into the Legislative Council of Bihar and Orissa, the purpose of which was an attempt to reduce the losses on this account by licensing miners and dealers; the bill was, however, rejected. In March, 1930, however, a similar bill to regulate the possession and transport of, and trading in, mica was passed, and from the figures presented since 1930, as analysed above, it appears that this bill may already have produced a good effect.

TABLE 24.—*Quantity and value of Mica produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Cwts. | Rs. | £ | Cwts. | Rs. | £ |
| *Bihar and Orissa—* | | | | | | |
| Gaya . . . | 6,051 | 3,21,283 | 23,799 | 8,597 | 3,93,619 | 29,595 |
| Hazaribagh . . | 25,577 | 13,43,216 | 99,497 | 15,500 | 6,41,847 | 48,250 |
| Monghyr . . | 92 | 5,222 | 387 | .. | .. | .. |
| *Madras—* | | | | | | |
| Nellore . . | 6,893 | 3,41,094 | 25,266 | 8,318 | 3,82,056 | 28,726 |
| Nilgiris . . | 65 | 10,936 | 810 | 51 | 7,869 | 592 |
| *Rajputana—* | | | | | | |
| Ajmer-Merwara . | 185 | 10,884 | 806 | 177 | 6,510 | 490 |
| Jaipur State . | 100 | 5,000 | 370 | 70 | 3,500 | 263 |
| TOTAL . | **38,963** | *20,37,634* | *150,935* | **32,713** | *14,35,401* | *107,925* |

TABLE 25.—*Quantity and value of Mica exported from India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Cwts. | Rs. | £ | Cwts. | Rs. | £ |
| *To—* | | | | | | |
| United Kingdom . | 22,891 | 24,05,167 | 178,160 | 22,889 | 18,60,262 | 139,869 |
| Germany . . | 3,831 | 2,00,931 | 14,884 | 5,018 | 2,39,505 | 18,008 |
| France . . | 4,810 | 97,992 | 7,259 | 788 | 87,719 | 6,595 |
| United States of America. | 12,378 | 7,18,550 | 53,226 | 11,264 | 5,44,569 | 40,945 |
| Other Countries . | 9,056 | 7,26,128 | 53,787 | 7,567 | 6,16,888 | 46,383 |
| TOTAL . | **52,966** | *41,48,768* | *307,316* | **47,921** | *33,48,943* | *251,800* |

## Monazite.

The monazite industry of Travancore, which was moribund in the year 1925, when the reported production was 1 cwt. only, showed signs of revival in 1926, the output amounting to 64·2 tons valued at £947. The production rose to 280 tons valued at £3,810 in 1927,

fell to 103·4 tons valued at £1,242 in 1928, and rose again to 180 tons valued at £1,800 in 1929. In 1930 the production fell again heavily to 14 tons valued at £140, but in 1931 rose again to 89·6 tons, valued at £890, and in 1932 to 654·3 tons valued at £6,147. The decline of the industry from the high figures of 1919 to 1921 is of course due to the supplanting of incandescent mantles for gas lighting by electricity. The increasing demand for ilmenite, occuring with the monazite and hitherto regarded as a bye-product, may be the means of reviving the industry by rendering cheaper production possible.

## Nickel.

As a bye-product in the melting operations of the Burma Corporation, Limited, at Namtu, in the Northern Shan States, there is now a regular production of nickel-speiss, which in 1927 amounted to 1,032 tons, in 1928 to 2,933 tons, in 1929 to 3,065 tons, and in 1930 to 3,150 tons. In 1931 the output fell somewhat to 2,911 tons valued at Rs. 6,73,973 (£49,924), rising again in 1932 to 3,580 tons valued at Rs. 10,27,677 (£77,269), and containing 25·98 per cent. of nickel, 12·87 per cent. of copper, and 32·99 ozs. of silver to the ton. This speiss is shipped to Hamburg for further treatment. It contains from 3 to 4 per cent. of cobalt.

## Petroleum.

The world's production of petroleum in 1926 amounted to nearly 150 million long tons, of which India contributed 0·72 per cent. In 1927, this figure jumped to some 172 million long tons, of which the Indian proportion, on a practically stationary production, fell to 0·64 per cent. In 1928, there was another substantial rise in the world's production, which reached the figure of over 181 million tons. In 1929, there was another jump to over 202 million tons, but in 1930 the world's production fell to about 193½ million tons, in 1931 to about 188 million tons, and in 1932 to about 180 million tons. The United States alone showed a fall greater than the total fall. Increases were shown by Roumania, Persia, Netherlands East Indies, Argentina, Trinidad, India, Germany, Czecho-Slovakia, Italy and Bolivia; Roumania showed the largest increase. All other producers showed a decrease in production. The United States contributed 59·9 per cent. of the world's supply in 1932, Russia 11·9 per cent. and Venezuela 8·9 per cent. In 1928, India contri-

buted 0·64 per cent., which fell to 0·60 per cent. in 1929 and rose to 0·62 in 1930, 0·63 per cent. in 1931 and 0·64 per cent. in 1932; her position on the list of petroleum producing countries fell from 11th in 1929 to 12th in 1930, 1931 and 1932, her place being taken by Trinidad.[1]

The production of petroleum in India (including Burma) rose from 305,018,751 gallons in 1931 to 308,606,031 gallons in 1932, the highest production yet recorded, with the exception of the output of 311,030,108 gallons in 1930. The increase in 1932 represents the balance of a considerable increase in the output of Burma, a slight increase of that of the Punjab, and of a trivial proportionate decrease in the production of Assam. This increase in output in 1932 was accompanied, however, by a decrease in value amounting to Rs. 83,44,212 (£561,514), or 12·8 per cent., the fall in price being a reflection of the world depression.

The amount of gasoline or petrol produced from natural gas during the year was 7,632,910 gallons, of which 7,089,206 gallons were produced in Burma and 543,704 gallons in the Punjab.

Production from Yenangyaung, the most highly developed field in the Indian Empire showed a decrease of 4,073,700 gallons, or a little over 3 per cent. of the 1931 total. It is interesting to note that the production in Yenangyaung still includes oil derived from the old Burmese hand-dug wells. This small volume of oil enjoys a sheltered market and the price at the river bank varied from Rs. 9 to Rs. 11 As. 4 per 100 viss during the year At the end of 1932 there were 3,028 producing wells in the Yenangyaung field, including 175 hand-dug wells, as against 3,095 producing wells, including 162 hand-dug wells, in 1931.

An interesting feature of the year was the discovery of oil at the horizon of the 3,000 and 3,100-feet sands in East Twingon. For many years these horizons have been recognised as gas sands, but it now appears that the gas in them is a crestal accumulation on the higher portions of the structure. This discovery proved a narrow strip of oil within the Twingon Reserve and led to competitive deepening towards the close of the year. Development of this part of the field, both by extension tests and by a deep test well, was proceeding at the end of the year. At Minlindaung one of the two deep test wells was abandoned, while the other remained shut down.

[1] Partly compiled from '*The Petroleum Times*' of 1st April 1932.

In 1932 there was an increase of approximately 3½ million gallons in the output of the Singu field. At the end of the year the total number of producing wells was 436 as compared with 489 in December 1931. In addition a number of wells remained cemented above productive sands. These wells can be drilled into the productive sands in a very short time and the total field production substantially increased.

No new horizons were discovered during the year. In Block 50 NE, a test well proved the existence of a deeper sand in this area, but the value of the sand is not yet known.

In 1932, the total production in the Pakokku district, including Lanywa, amounted to 23,067,644 gallons, this figure including an outturn of 44,476 gallons from hand-dug wells at Yenangyat. In the Yenangyat field proper 19 new wells were drilled and put to production and, in addition, 6 wells were deepened and put to production. At the end of the year there were 179 in the producing wells in the Pakokku district, excluding Lanywa. No new horizons were proved during the year.

In 1931 the total production from the Lanywa field was 16,437,000 gallons; in 1932 the total production increased to 19,711,994 gallons. The work of filling in behind the embankment with the object of rendering the area permanently above high-water level was continued and at the end of the year preparations were in hand for a further extension of the embankment.

The construction of the power station was completed and at the end of the year electric power was used for all purposes other than drilling. The surplus gas was sufficient for firing boilers for drilling and by the end of the year the importation of fuel oil had ceased. The gasoline plant, which had been shut down since October 1931, was again operated during the latter half of the year under report.

In the Minbu district there were, at the close of the year, 358 producing wells, including one gas well, giving a total production of 3,850,716 gallons. Apart from routine production there was very little activity in the district during the year.

In 1932 the total production from the Indaw field was 4,040,690 gallons. An extension of the productive area was proved during the year, but it will take some time to test the whole of the new area.

The Thayetmyo fields, which had shown a large decline in 1928, amounting to over 272,000 gallons, showed in 1929 a small increase

of some 19,000 gallons; but in 1930 there was a further substantial decrease in production amounting to some 242,000 gallons. During 1931 activities were considerably hampered by the disturbed conditions prevailing in the district, but an increase of some 74,000 gallons was shown in the production of these fields. In 1932 production decreased by some 113,000 gallons.

The output from Kyaukpyu remained at its usual low level.

Owing to the unfavourable economic conditions during 1932 there was little activity in areas outside the producing fields of Burma.

In Assam there was a small increase in the output of the Digboi field. No new areas have yet been proved in the Assam Valley.

In the Surma Valley the output from the Badarpur field decreased by over 1,100,000 gallons, due to the natural decline of the oilsands, which could no longer be offset by drilling and reconditioning. At Masimpur no oil was produced during the year, and attention was confined to new drilling; whilst at Patharia there was a small production incidental to reconditioning operations.

In the Punjab, the output from the Khaur field showed a slight increase amounting to about 350,000 gallons. No important new supply was, however, obtained from the deep sands during the year.

TABLE 26.—*Quantity and value of Petroleum produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Gals. | Rs. | £ | Gals. | Rs. | £ |
| *Assam*— | | | | | | |
| Badarpur | 1,985,042 | 3,12,644 | 23,159 | 847,217 | 63,357 | 4,764 |
| Digboi | 53,407,990 | 91,19,891 | 675,548 | 54,198,185 | 92,54,823 | 695,851 |
| Patharia | 153,431 | 24,165 | 1,789 | 89,854 | 7,919 | 595 |
| *Burma*— | | | | | | |
| Kyaukpyu | 13,068 | 11,829 | 876 | 13,237 | 11,814 | 888 |
| Minbu | 3,993,633 | 7,98,726 | 59,165 | 3,850,716 | 6,25,750 | 47,049 |
| Singu | 85,476,378 | 1,70,95,676 | 1,266,346 | 88,941,939 | 1,44,53,065 | 1,086,697 |
| Thayetmyo | 577,840 | 1,15,568 | 8,561 | 464,326 | 75,453 | 5,673 |
| Upper Chindwin | 2,777,102 | 2,09,427 | 15,513 | 4,040,690 | 3,03,051 | 22,786 |
| Yenangyat (including Lanywa). | 19,809,104 | 39,61,821 | 293,468 | 28,067,644 | 37,55,163 | 282,343 |
| Yenangyaung | 181,265,448 | 2,60,96,078 | 1,933,043 | 127,191,743 | 2,07,65,523 | 1,561,318 |
| *Punjab*— | | | | | | |
| Attock | 5,557,720 | 13,89,430 | 102,921 | 5,900,480 | 14,75,120 | 110,911 |
| TOTAL | [illegible] | *5,91,35,250* | *4,380,389* | [illegible] | *5,07,91,038* | *3,818,875* |

TABLE 27.—*Imports of Kerosene Oil into India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Gals. | Rs. | £ | Gals. | Rs. | £ |
| *From—* | | | | | | |
| Russia . . | 3,021,170 | 15,54,948 | 115,181 | 60,210 | 22,579 | 1,698 |
| Georgia . . | 19,455,551 | 98,51,428 | 729,735 | 28,268,908 | 1,21,86,262 | 916,260 |
| Azerbaijan . . | 11,758,283 | 51,87,107 | 384,230 | 17,211,968 | 65,24,430 | 490,559 |
| Persia . . | 11,001,437 | 51,71,125 | 383,046 | 18,058,144 | 98,97,711 | 744,189 |
| Straits Settlements (including Labuan). | 428,383 | 2,16,949 | 16,070 | 6,500 | 1,979 | 149 |
| Borneo . . | 2,285,007 | 11,40,750 | 84,500 | 2,181,860 | 8,72,149 | 65,575 |
| Celebes and other Islands. | 5,502,314 | 28,08,474 | 208,085 | 1,318,023 | 8,20,638 | 61,702 |
| United States of America | 19,592,798 | 1,27,58,851 | 944,780 | 6,080,904 | 31,10,836 | 233,897 |
| Other countries . | 136 | 95 | 7 | 4,920,055 | 28,02,234 | 178,100 |
| TOTAL . | 72,997,029 | *3,86,84,722* | *2,865,534* | 78,091,572 | *3,57,38,818* | *2,687,129* |

TABLE 28.—*Imports of Fuel Oils into India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Gals. | Rs. | £ | Gals. | Rs. | £ |
| *From—* | | | | | | |
| Persia . . . | 72,295,499 | 1,41,86,900 | 1,050,882 | 67,938,453 | 1,31,09,255 | 985,658 |
| Straits Settlements (including Labuan). | 2,665,515 | 5,41,717 | 40,127 | 69,899 | 19,314 | 1,452 |
| Borneo . . | 25,681,729 | 54,28,436 | 402,106 | 26,518,898 | 52,01,654 | 391,102 |
| Other countries . | 3,672,058 | 8,78,497 | 65,074 | 10,730,442 | 20,96,511 | 157,632 |
| TOTAL . | 104,314,801 | *2,10,35,550* | *1,558,189* | 105,[illegible] | 2,04,26,734 | *1,535,844* |

TABLE 29.—*Exports of Paraffin Wax from India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *To*— | | | | | | |
| United Kingdom | 15,314 | 68,84,084 | 509,932 | 11,627 | 53,27,597 | 400,571 |
| Germany | 789 | 3,32,226 | 24,609 | 1,420 | 5,98,650 | 45,011 |
| Netherlands | 2,946 | 12,65,954 | 93,774 | 4,780 | 20,36,800 | 153,105 |
| Belgium | 2,850 | 12,46,350 | 92,322 | 3,501 | 15,11,800 | 113,669 |
| Spain | 900 | 3,78,000 | 28,000 | .. | .. | .. |
| Italy | 2,995 | 12,57,900 | 93,178 | 4,080 | 16,92,600 | 127,268 |
| China | 6,045 | 28,42,044 | 210,522 | 2,000 | 8,67,446 | 65,222 |
| Japan | 440 | 1,88,300 | 13,948 | 1,795 | 7,90,300 | 59,421 |
| Union of South Africa. | 3,082 | 14,48,340 | 107,284 | 2,195 | 10,47,549 | 78,763 |
| Portuguese East Africa. | 3,720 | 20,31,774 | 150,502 | 4,619 | 24,09,785 | 181,187 |
| Canada | 857 | 3,59,940 | 26,662 | 1,270 | 5,33,400 | 40,105 |
| United States of America. | 5,630 | 24,00,300 | 177,800 | 3,950 | 16,59,000 | 124,737 |
| Mexico | 1,450 | 6,09,000 | 45,111 | 3,679 | 15,45,574 | 116,209 |
| Chile | 2,516 | 11,88,740 | 88,055 | 869 | 4,16,710 | 31,332 |
| Australia | 293 | 1,25,790 | 9,318 | 297 | 1,26,420 | 9,505 |
| New Zealand | 63 | 37,660 | 2,790 | 20 | 8,820 | 663 |
| Other countries | 1,712 | 7,41,515 | 54,927 | 1,106 | 4,65,850 | 35,026 |
| TOTAL | **51,602** | *2,33,37,917* | *1,728,734* | **47,108** | *2,10,37,801* | *1,581,789* |

There was a small increase (5 million gallons) in the imports of kerosene, due to increases from Georgia (9 million gallons), Persia (7 million gallons) and Azerbaijan (5½ million gallons) more than neutralising the falls of imports from the United States (13½ million gallons), Russia (3 million gallons), Netherlands East Indies (4 million gallons) and the Straits Settlements and Labuan (400,000 gallons).

The quantity of fuel oil imported into India during 1932 was, as Table 28 will show, nearly one million gallons greater than that received during the previous year, the total imports for the year under review being a little over 105 million gallons. Some 64½ per cent. of the supply was derived from Persia and some 25 per cent. from Borneo.

The exports of paraffin wax again showed a decrease, amounting to some 4,500 tons. (*See* Table 29.)

## Ruby, Sapphire and Spinel.

A severe fall in the output from the Mogok ruby mines of Upper Burma in 1924, followed in 1925 by a marked drop in value, bore witness to a serious decline in the industry. The Burma Ruby Mines, Limited, ultimately decided to go into liquidation, and the mines were offered for sale in September 1926. The skeleton organisation left in charge of the mines, however, made good use of its opportunities, with the result that the value of the output in 1926 exceeded that of the previous year by over a *lakh* of rupees. This encouraging result was effected by a rigorous economy and an extension of a system of co-operation with local miners, and was assisted by some good finds of sapphires in the Kyaungdwin mine, the only one still worked by European methods.

During 1927, however, production fell in value by over $1\frac{3}{4}$ *lakhs* of rupees, due mainly to a decrease in the value of the sapphires and spinels produced, there having been a slight increase in the value of the rubies. During 1928, there was another very large decline in value, amounting to over a *lakh* of rupees, due to a severe drop in the value of the sapphires produced; as before, there was a slight increase in the value of the rubies. The value of the 1929 production was slightly above that of 1928, due to a considerable increase in the value of the rubies found, largely balanced by another large fall in the value of sapphires produced. In 1930 there was a further substantial fall in production and in total value, though the value per carat of the sapphires produced is the highest recorded for many years. Judging from reports in the *Rangoon Times*, this is due to the opening up by the Burma Ruby Mines, Ltd., of the new Pagoda mine at Kathe, leading to the find of a fine sapphire of 630 carats and a star sapphire of 293 carats. The find of a ruby of 100 carats was also reported. The great drop in production recorded in 1931 was due to the cessation of operations of the Burma Ruby Mines, Limited. Though the industry is in a very depressed state, work is still continued by local miners, but of this no reliable statistics are available. For 1932 no returns are available, except that a fine ruby of 17 carats was found at Chaunggyi near Mogok, and a fine sapphire of about 90 carats and a good star sapphire of 453 carats were mined at Kathe.

Table 30.—*Quantity and value of Ruby, Sapphire and Spinel produced in India during the year 1931 and 1932.*

| — | | 1931. | | | 1932. | |
|---|---|---|---|---|---|---|
| | | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value. |
| | | Carats. | Rs. | £ | | |
| Burma | (Rubies) (a) | | 40,364 | 2,990 | .. | .. |
| | (Sapphires) (a) | | 2,500 | 185 | .. | .. |
| | (Spinel) | | .. | .. | .. | .. |
| Total | | .. | *42,864* | *3,175* | (b) | (b) |

(a) Not available. (b) No figures received.

## Salt.

There was a large decrease in the total output of salt amounting to some 228,000 tons, shared by Madras (108,893 tons), Bombay and Sind (83,638 tons), and Northern India (43,317 tons), partially balanced by small increases in Aden (5,204 tons) and Burma (2,110 tons). Imports of salt into India increased slightly by 24,147 tons, all the countries of origin showing increases, excepting Italian East Africa, Spain, and 'other countries'.

Table 31.—*Quantity and value of Salt produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| Aden | 286,087 | 31,69,172 | 234,758 | 291,241 | 32,24,898 | 242,474 |
| Bombay and Sind | 489,052 | 22,83,669 | 169,161 | 405,414 | 19,32,468 | 145,298 |
| Burma | 22,974 | 3,48,831 | 25,839 | 25,084 | 4,26,438 | 32,063 |
| Gwalior | 48 | 2,647 | 196 | 48 | 1,744 | 131 |
| Madras | 555,449 | 38,83,284 | 287,647 | 446,556 | 26,95,736 | 202,687 |
| Northern India | 485,840 | 39,58,406 | 292,845 | 442,523 | 30,72,149 | 276,101 |
| Total | 1,839,450 | *1,36,46,009* | *1,010,441* | 1,610,861 | *1,13,53,433* | *898,754* |

TABLE 32.—*Quantity and value of Rock-Salt produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| Salt Range . . | 136,544 | 10,44,559 | 77,375 | 148,516 | 11,36,150 | 85,425 |
| Kohat . . . | 21,123 | 66,509 | 4,927 | 19,972 | 62,796 | 4,721 |
| Mandi . . . | 4,226 | 1,09,508 | 8,111 | 3,555 | 93,482 | 7,029 |
| TOTAL . | 161,893 | *12,20,571* | *90,413* | 172,043 | *12,92,428* | *97,175* |

TABLE 33.—*Imports of Salt into India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *From*— United Kingdom | 24,164 | 5,17,170 | 38,309 | 31,991 | 5,93,714 | 44,640 |
| Germany . . | 43,097 | 7,90,671 | 58,568 | 49,478 | 8,57,889 | 64,503 |
| Spain . . . | 27,264 | 4,00,558 | 29,671 | 25,994 | 3,72,953 | 28,042 |
| Aden and Dependencies | 273,166 | 40,90,366 | 302,990 | 304,229 | 44,23,875 | 332,622 |
| Egypt . . . | 6,907 | 5,80,965 | 43,034 | 38,509 | 5,64,995 | 42,481 |
| Italian East Africa | 109,904 | 15,30,617 | 113,379 | 96,500 | 13,27,124 | 99,784 |
| Other countries . | 14,092 | 1,32,451 | 9,811 | 6,040 | 91,957 | 6,914 |
| TOTAL . | 523,594 | *80,42,798* | *595,762* | 552,741 | *82,32,507* | *618,986* |

## Saltpetre.

Although statistics of production of saltpetre in India are no longer available, the export figures may be accepted as a fairly reliable index to the general state of the industry. Excepting a few hundreds of tons required for internal consumption as fertiliser, most of the output is exported to foreign countries. The quantity exported in 1932 amounted to 165,782 cwts. valued at Rs. 12,27,321 (£92,272), against 123,117 cwts. valued at Rs. 9,91,087 (£73,414) in 1931.

A certain amount of nitrate of potash is used for agricultural purposes on the tea gardens of India. During the war, when it was impossible to obtain supplies of imported potash, the amount of locally produced nitrate utilised in this way reached an appreciable figure. The practice continued and the quantities estimated to have been absorbed for fertilising purposes on tea gardens in 1923, 1924, 1925, 1926, 1927, 1928, 1929, 1930 and 1931 were 1,000, 1,100, 800, 700, 500, 250, 300, 800 and 680 tons respectively. In 1932, this figure is estimated to have been 730 tons only. The gradual decrease since the year 1925 is due to the fact that it was found cheaper to employ a mixture of imported sulphate of ammonia and nitrate of potash.[1] The increased consumption in 1930 to 1932 was due to the nitrate being available at lower rates.

TABLE 34.—*Distribution of Saltpetre exported from India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Cwts. | Rs. | £ | Cwts. | Rs. | £ |
| *To—* | | | | | | |
| United Kingdom . . | 26,499 | 2,10,274 | 15,576 | 55,832 | 4,25,567 | 31,997 |
| Ceylon . . . . . | 55,480 | 3,33,657 | 24,715 | 36,373 | 2,09,327 | 15,789 |
| Straits Settlements (including Labuan). | 1,701 | 14,998 | 1,111 | 3,346 | 42,031 | 3,160 |
| Mauritius and Dependencies | 38,379 | 4,14,614 | 30,712 | 56,715 | 3,86,897 | 29,090 |
| Other Countries . . | 1,058 | 17,544 | 1,300 | 13,516 | 1,63,499 | 12,286 |
| TOTAL . | **123,117** | *9,91,087* | *73,414* | **165,782** | *12,27,321* | *92,272* |

[1] From information kindly supplied by Messrs. Shaw, Wallace & Co.

## Silver.

In contrast with the increases in the production of silver from the Bawdwin mines of Upper Burma, amounting to 1,400,291 ozs. recorded during the four years, 1925 to 1928, the following years 1929, 1930 and 1931 were marked by decreases amounting to 124,211 ozs., 226,311 ozs., and 1,153,806 ozs. respectively. In 1932, however, there was a small increase again, amounting to 98,556 ozs. These variations in quantity were accompanied by a small fall of value in 1929, marked falls in 1930 and 1931, and a marked rise in 1932. The output of silver obtained as a bye-product from the Kolar gold mines of Mysore showed an increase of some 5,000 ozs. The amount of silver bullion and coin exported during the year was 34,664,148 ozs. valued at Rs. 4,15,61,144 (£3,124,898).

TABLE 35.—*Quantity and value of Silver produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Ozs. | Rs. | £ | Ozs. | Rs. | £ |
| *Burma*—<br>Northern Shan States . . | 5,900,400 | 51,97,367 | 384,990 | 5,998,956 | 62,32,915 | 468,640 |
| *Mysore*—<br>Kolar . . . . . | 22,605 | 31,867 | 2,361 | 27,781 | 38,796 | 2,917 |
| TOTAL . | **5,923,005** | *52,29,234* | *387,351* | **6,026,737** | *62,71,711* | *471,557* |

## Tin.

Following a series of years of practically continuous increase, a slight decrease in the production of tin-ore in Burma was reported for the year 1931, during which the output amounted to 4,255·2 tons valued at Rs. 35,07,380 (£259,806). In 1932, however, there was again an increase in production to 4,525 tons valued at Rs. 45,09,995 (£339,097). This is the highest quantity (but not the highest total value, for which the smaller outputs of 1926, 1927, 1929, 1930 and 1931 showed higher figures) yet recorded in any one year. The considerable increase in the total value is, of course, mainly due to the rise in the price of the metal during the year resulting from the tin restriction scheme in operation in the five leading tin producing countries, Malaya, Netherlands East Indies, Bolivia, Nigeria and Siam, a scheme to which India is not an adherent. This increase in output of some 270 tons is the balance of an increase from Tavoy and Mergui and a decrease from Mawchi in the Southern Shan States. Milling operations were suspended at Mawchi in August 1927 pending the installation of additional plant and further development. Milling was resumed in February 1930 and this explains the large increases of 1930 and 1931. The figure for 1932 includes 1,557·3 tons from Mawchi, calculated to be the proportion of tin-ore in 2,732 tons of concentrates derived from mixed wolfram-scheelite-cassiterite-ore; these concentrates are assumed to contain 43 per cent. of wolfram and 57 per cent. of cassiterite. There was no reported output of block tin.

Imports of unwrought tin increased from 41,969 cwts. valued at Rs. 36,28,556 (£268,782) in 1931 to 49,279 cwts. valued at Rs. 47,50,341 (£357,168) in 1932; over 98 per cent. of these imports came from the Straits Settlements.

TABLE 36.—*Quantity and value of Tin-ore produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Burma*— | | | | | | |
| Amherst . . . . | 17·0 | 17,683 | 1,310 | 19·2 | 22,712 | 1,708 |
| Mergui . . . . | 497·4 | 3,96,304 | 29,356 | 598·0 | 5,44,332 | 40,927 |
| Southern Shan States . | (a)1,695·0 | 13,96,680 | 103,458 | (a)1,557·3 | 15,52,129 | 116,701 |
| Tavoy . . . . | 2,044·8 | 16,96,218 | 125,645 | 2,349·6 | 23,89,826 | 179,686 |
| Thaton . . . . | 1·0 | 500 | 37 | 0·9 | 996 | 75 |
| TOTAL . | **4,255·2** | *35,07,380* | *259,806* | **4,525·0** | *45,09,995* | *339,097* |

(*a*) Estimated.

TABLE 37.—*Imports of unwrought Tin (blocks, ingots, bars and slabs) into India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Cwts. | Rs. | £ | Cwts. | Rs. | £ |
| *From*— | | | | | | |
| United Kingdom . . | 733 | 61,680 | 4,569 | 773 | 74,419 | 5,595 |
| Straits Settlements (including Labuan). | 41,133 | 35,58,768 | 263,612 | 48,881 | 46,65,296 | 350,774 |
| Other countries . . | 103 | 8,108 | 601 | 125 | 10,626 | 799 |
| TOTAL . | **41,969** | *36,28,556* | *268,782* | **49,779** | *47,50,341* | *357,168* |

## Tungsten.

During the three years 1926 to 1928 there was a fall in the output of wolfram from 1,484 tons in 1926 to 622 tons in 1928, the last being valued at Rs. 2,99,549 (£22,354). In 1929, the output rose again to 1,348·4 tons valued at Rs. 15,16,795 (£113,193), and in 1930 to 2,451·5 tons valued at Rs. 18,09,881 (£134,065), declining slightly to 2,247·7 tons valued at Rs. 8,81,665 (£65,309) in 1931, and 2,022·9 tons valued at Rs. 7,03,852 (£52,921) in 1932. The production of 1930 was the highest since the collapse of the industry at the end of the war and is close to the figure for 1920 (2,346·2 tons valued at £139,707) both in quantity and value. The figures for

1931 and 1932 include 1,279 tons and 1,174·8 tons respectively from Mawchi, calculated to be the proportion of wolfram in concentrates (assumed to contain 43 per cent. of wolfram and 57 per cent. of cassiterite) derived from the mixed wolfram-scheelite-cassiterite-ore.

The output of Tavoy declined from 870·4 tons valued at Rs. 3,51,609 (£26,045) in 1931, to 751·4 tons valued at Rs. 2,61,840 (£19,687) in 1932.

TABLE 38.—*Quantity and value of Tungsten-ore produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Burma*— | | | | | | |
| Mergui | 98·3 | 28,688 | 2,125 | 96·7 | 33,253 | 2,500 |
| Southern Shan States | 1,279·0 | 5,01,368 | 37,139 | 1,174·8 | 4,08,759 | 30,734 |
| Tavoy | 870·4 | 3,51,609 | 26,045 | 751·4 | 2,61,840 | 19,687 |
| TOTAL | 2,247·7 | *8,81,665* | *65,309* | 2,022·9 | *7,03,852* | *52,921* |

## Zinc.

The production of zinc concentrates by the Burma Corporation, Limited, in the Northern Shan States, fell from 51,455 tons valued at Rs. 17,23,528 (£127,669) in 1931 to 44,484 tons valued at Rs. 15,09,298 (£113,481) in 1932. The slight rise in the value per ton is parallel with a similar rise in the price of spelter. The exports during the year under review amounted to 49,950 tons valued at Rs. 24,97,500 (£187,782), against 54,818 tons valued at Rs. 28,41,250 (£210,463) in the preceding year.

## Zircon.

The output of zircon, a mineral obtained as a concurrent product in the collection of ilmenite and monazite in Travancore State, decreased from 845·6 tons valued at £7,972 in 1931 to 490·6 tons valued at £3,805 in 1932. There was a parallel decrease in the output of monazite, but a large increase in the output of ilmenite during the same year.

## III.—MINERALS OF GROUP II.

**Agate.**

The agate mines of Rajpipla State, Bombay Presidency, which had not been worked since 1917, were the source in 1929 of an output of 148·7 cwts. valued at Rs. 8,000 (£597). In 1930, 1931 and 1932 there was again no production.

**Alum.**

The output of alum in the Mianwali district, Punjab, amounted to only 478 cwts. valued at Rs. 5,525 (£412) in 1928. Since then there has been no manufacture owing to the low market rate.

**Amber.**

The production of amber in the Myitkyina district, Burma, decreased from 29·5 cwts. valued at Rs. 12,020 (£897) in 1928, to 19·6 cwts. valued at Rs. 6,080 (£454) in 1929, and 2·1 cwts. valued at Rs. 730 (£54) in 1930. There was no reported output in 1931, but in 1932 there was an output of 11·5 cwts. valued at Rs. 1,940 (£146).

**Apatite.**

The production of apatite in the Singhbhum district, Bihar and Orissa, was 22 tons valued at Rs. 3,300 (£244) in 1930, but *nil* in 1931 and 1932. The output of apatite in the Trichinopoly district, Madras, rose slightly from 109 tons valued at Rs. 1,067 (£79) in 1931 to 121 tons valued at Rs 1,071 (£81) in 1932.

**Asbestos.**

There was a decrease in the total production of asbestos from 318·4 tons valued at Rs. 16,160 (£1,206) in 1929 to 33·2 tons valued at Rs. 1,190 (£88) in 1930. This was entirely derived from the Cuddapah district, Madras. The mines in Mysore and Seraikela State were not worked in 1930, and in 1931 the Cuddapah mines also ceased producing. A small output of 6 tons valued at Rs. 70 (£5) was reported from the Ajmer-Merwara district during 1931. In 1932 Seraikela State, Bihar and Orissa, yielded 90 tons of asbestos valued at Rs. 9,000 (£677).

**Barytes.**

The production of barytes in India fell from 5,654 tons valued at Rs. 43,206 (£3,200) in 1931 to 2,957 tons valued at Rs. 29,372 (£2,209) in 1932. This fall was entirely due to decreased production from Kurnool, the other producing districts showing an increase as is shown in Table 39.

TABLE 39.—*Quantity and value of Barytes produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Madras*— | | | | | | |
| Anantapur . . . . | .. | .. | .. | 166 | 1,726 | 129 |
| Cuddapah . . . . | 1,335 | 13,350 | 989 | 1,359 | 18,535 | 1,393 |
| Kurnool . . . . | 4,158 | 28,890 | 2,140 | 949 | 6,213 | 467 |
| *Rajputana*— | | | | | | |
| Alwar State . . . | 161 | 966 | 71 | 483 | 2,898 | 220 |
| TOTAL . | **5,654** | ***43,206*** | ***3,200*** | **2,957** | ***29,372*** | ***2,209*** |

In 1930, 2,514 tons of bauxite valued at Rs. 20,112 (£1,490) were produced, of which 719 tons came from the Kaira district of Bombay, and 1,795 tons from the Jubbulpore district of the Central Provinces. In 1931 and 1932 no bauxite was mined.

**Bauxite.**

In Jaipur State, Rajputana, 20 cwts. of beryl were extracted in 1930; no value was reported. There was no output in 1931, but in 1932 there was a production of 281 tons valued at Rs. 5,281 (£397).

**Beryl.**

The production of native bismuth from the Tavoy district, Burma, fell from 112 lbs. valued at Rs. 323 (£24) in 1930, to 42 lbs. valued at Rs. 84 (£6) in 1931, and 27 lbs. valued at Rs. 54 (£4) in 1932.

**Bismuth.**

Borax is sometimes produced from the Puga valley in the Ladakh *tahsil* of Kashmir State, but there was no production during the years 1931 and 1932.

**Borax.**

The total estimated value of building materials and road-metal produced in the year under consideration was Rs. 91,22,170 (£685,877). Certain returns supplied in cubic feet have been converted into tons on the basis of certain assumed relations between volume and weight.

**Building Materials and Road-metal.**

There was a decrease in the recorded production of clays, which fell from 169,593 tons valued at Rs. 3,45,805 (£25,615) in 1931, to 130,884 tons valued at Rs. 2,58,701 (£19,451) in 1932. All provinces showed decreases except Burma, Rajputana, Gwalior and Kashmir.

**Clays.**

**TABLE 40.—*Production of Building Materials***

| | Granite and Gneiss. | | Laterite. | | Lime. | | Limestone and Kankar. | |
|---|---|---|---|---|---|---|---|---|
| — | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. |
| | Tons. | Rs. | Tons. | Rs. | Tons. | Rs. | Tons. | Rs. |
| Assam . . . | 6,972 | 25,131 | 19,129 | 58,723 | .. | .. | 53,551 | 39,627 |
| Bengal . . . | 82,109 | 52,918 | .. | .. | .. | .. | .. | .. |
| Bihar and Orissa . | 468,779 | 4,28,942 | 369 | 143 | .. | .. | 629,745 | 12,52,568 |
| Bombay . . . | .. | .. | 3,565 | 6,043 | .. | .. | .. | .. |
| Burma . . . | 187,452 | 4,82,860 | 101,920 | 1,86,768 | .. | .. | 184,196 | 2,67,414 |
| Central India . . | .. | .. | .. | .. | .. | .. | 118,816 | 49,942 |
| Central Provinces . | 37,250 | 33,196 | 8,798 | 7,885 | 13,787 | 1,14,361 | 289,253 | 3,26,770 |
| Gwalior . . . | .. | .. | .. | .. | .. | .. | 55,862 | 32,853 |
| Kashmir . . | .. | .. | .. | .. | .. | .. | .. | .. |
| Madras . . . | 157,464 | 1,75,564 | 73,354 | 67,796 | .. | .. | 19,640 | 12,737 |
| Mysore . . . | .. | .. | 159 | 1,719 | 7,672 | 1,12,435 | 1,058 | 5,812 |
| N.-W. F. Province . | .. | .. | .. | .. | .. | .. | 2,349 | 866 |
| Punjab . . . | 161,201 | 1,65,205 | .. | .. | .. | .. | 220,747 | 2,40,319 |
| Rajputana . . | .. | .. | .. | .. | .. | .. | (a)182,046 | 2,57,816 |
| United Provinces . | 45,630 | 1,04,304 | .. | .. | .. | .. | (b)243,821 | 2,82,845 |
| TOTAL . | [illegible] | *14,68,129* | 207,294 | *3,28,577* | 21,459 | *2,26,796* | 2,001,964 | *27,78,560* |

(a) Includes 87 tons of dolomite produced in Jaisalmer State.
(b) Includes [illegible] tons of *kankar*.

*and Road-metal in India during the year 1932.*

| Marble. | | Sandstone. | | Slate. | | Trap. | | Miscellaneous. | | Total Value (£1 = Rs. 13·3). | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Quantity. | Value. | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. | | |
| Tons. | Rs. | Tons. | Rs. | Tons. | Rs. | Tons. | Rs. | Tons. | Rs. | Rs. | £ |
| .. | .. | 12,512 | 20,809 | .. | .. | .. | .. | 232,030 | 3,46,911 | 4,91,201 | 36,932 |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 52,918 | 3,979 |
| .. | .. | 20,285 | 27,252 | 1,538 | 44,024 | 84,601 | 60,973 | 77,920 | 40,124 | 18,54,036 | 139,400 |
| .. | .. | .. | .. | .. | .. | 196,953 | 2,85,686 | 46,504 | 38,390 | 3,30,119 | 24,821 |
| .. | .. | 107,175 | 1,83,715 | .. | .. | .. | .. | 844,334 | 10,17,724 | 21,38,490 | 160,780 |
| .. | .. | 2,025 | 513 | .. | .. | .. | .. | 2,421 | 10,488 | 60,943 | 4,582 |
| .. | .. | .. | .. | .. | .. | .. | .. | 71,227 | 54,150 | 5,35,862 | 40,290 |
| .. | .. | 8,224 | 14,796 | .. | .. | .. | .. | .. | .. | 47,649 | 3,583 |
| .. | .. | .. | .. | .. | .. | .. | .. | 8,879 | 10,076 | 10,076 | 758 |
| .. | .. | .. | .. | .. | .. | 6,005 | 6,650 | 397,424 | 3,64,697 | 6,27,444 | 47,176 |
| .. | .. | 525 | 2,205 | 15 | 45 | .. | .. | 63,636 | 1,45,031 | 2,67,247 | 20,094 |
| .. | .. | .. | .. | .. | .. | .. | .. | 4,283 | 1,654 | 2,520 | 189 |
| .. | .. | .. | .. | 6,260 | 1,29,272 | .. | .. | 13,663 | 6,192 | 5,49,979 | 41,352 |
| 4,964 | 1,76,185 | 185,532 | 6,57,775 | 360 | 1,260 | .. | .. | 17,290 | 25,230 | 11,18,266 | 84,080 |
| .. | .. | 3,263 | 3,662 | 177 | 354 | .. | .. | 268,870 | 6,44,265 | 10,35,430 | 77,852 |
| **4,964** | *1,76,185* | **339,541** | *9,10,727* | **8,350** | *1,74,955* | **287,559** | *3,53,309* | **2,043,490** | *27,04,932* | *91,22,170* | *685,877* |

TABLE 41.—*Production of Clays in India during the year 1932.*

| — | 1932. | | |
|---|---|---|---|
| | Quantity. | Value (£1=Rs. 13·3). | |
| | Tons. | Rs. | £ |
| Assam | 6,495 | 29,238 | 2,198 |
| Bengal | 12,487 | 24,413 | 1,835 |
| Bihar and Orissa | 20,898 | 1,08,028 | 8,123 |
| Burma | 21,788 | 24,914 | 1,873 |
| Central Provinces | 27,396 | 29,176 | 2,194 |
| Gwalior | 378 | 1,365 | 103 |
| Kashmir | 11 | 12 | 1 |
| Madras | 3,102 | 1,005 | 76 |
| Mysore | 17,450 | 25,558 | 1,921 |
| Punjab | 16,089 | 2,514 | 189 |
| Rajputana | 4,790 | 12,478 | 938 |
| TOTAL | **130,884** | *2,58,701* | *19,451* |

Columbite.

An output of 100 lbs. of columbite valued at Rs. 60 (£4) was reported from the Monghyr district, Bihar and Orissa, during 1931. There was no output in 1932.

Corundum.

The production of corundum in the Salem district, Madras, amounted to 30 tons valued at Rs. 2,189 (£162) in 1930, but there was no production during 1931 and 1932.

Felspar.

There was an output in 1931 of 334 tons of felspar valued at Rs. 3,335 (£247), of which 333 tons came from Ajmer-Merwara and only 1 ton from Alwar State, Rajputana. In 1932 the output was 473 tons valued at Rs. 4,388 (£330), entirely from Ajmer-Merwara.

Fuller's earth.

In reversal of the previous year's record, the reported production of fuller's earth increased from 2,958 tons in 1931 to 4,359 tons in 1932. The chief increase was in Bikaner State, with smaller increases in Jodhpur State and Hyderabad (Sind).

TABLE 42.—*Quantity and value of Fuller's earth produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Bombay*— | | | | | | |
| Hyderabad (Sind) . . | 473 | 10,453 | 774 | 789 | 13,410 | 1,008 |
| *Central Provinces*— | | | | | | |
| Jubbulpore . . . | 38 | 186 | 14 | 19 | 93 | 7 |
| *Rajputana*— | | | | | | |
| Bikaner State . . . | 1,146 | 8,098 | 600 | 2,193 | 15,493 | 1,165 |
| Jaisalmer State . . | 15 | 178 | 13 | 16 | 180 | 14 |
| Jodhpur State . . . | 1,286 | 15,400 | 1,141 | 1,342 | 16,100 | 1,211 |
| TOTAL . | 2,958 | *34,315* | *2,542* | 4,359 | *45,282* | *3,405* |

**Garnet.** There was an output of 480 tons of garnet sand valued at Rs. 1,200 (£90) in 1928, in the Tinnevelly district, Madras. In 1929 no garnet was produced, but in 1930 there was an output of 7·3 tons of garnet valued at Rs. 175 (£13) in Jaipur State, Rajputana, in 1930. In 1931 no garnet was produced in India, but in 1932 there was an output of 147 tons of garnet from the Tinnevelly district.

**Graphite.** There was an output of 6·5 tons of graphite in the Kistna district of Madras in 1931, whilst 5 tons of graphite were produced in the Kistna district in 1932.

**Gypsum.** There was a small increase in the output of gypsum from 53,632 tons valued at Rs. 97,938 (£7,254) in 1931, to 54,741 tons valued at Rs. 94,768 (£7,125) in 1932.

TABLE 43.—*Quantity and value of Gypsum produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Kashmir State* . . . | 59 | 65 | 5 | 86 | (a) | .. |
| *Madras*— | | | | | | |
| Trichinopoly . . . | 4 | 41 | 3 | 75 | 820 | 62 |
| *Punjab*— | | | | | | |
| Jhelum . . . . | 16,792 | 18,102 | 1,341 | 12,726 | 13,150 | 988 |
| *Rajputana*— | | | | | | |
| Bikaner State . . . | 19,572 | 35,029 | 2,595 | 22,296 | 28,955 | 2,177 |
| Jaisalmer State . . | 205 | 1,201 | 88 | 235 | 913 | 69 |
| Jodhpur State . . . | 17,000 | 43,500 | 3,222 | 16,000 | 42,500 | 3,195 |
| *United Provinces*— | | | | | | |
| Agra . . . . | .. | .. | .. | 3,320 | 8,426 | 634 |
| Garhwal . . . . | .. | .. | .. | 3 | 4 | .. |
| TOTAL . | 53,632 | *97,938* | *7,254* | 54,741 | *94,768* | *7,125* |

(a) Not reported.

Miscellaneous refractory minerals.

The output of kyanite and quartzite and related rocks in Bihar and Orissa is becoming increasingly important, partly for purposes of export, and partly for use in India, such as for furnace linings at Jamshedpur; but in 1931 there was a fall to a quarter of the 1930 output. In 1932, however, there was again an increase. The data for 1931 and 1932, which all relate to the Singhbhum district, except for 3 tons of kyanite produced in Ajmer-Merwara, Rajputana, are assembled in Table 44, from which it will be seen that there has been an increase in total output from 9,716 tons valued at Rs. 68,963 (£5,108) in 1931, to 14,148 tons valued at Rs. 1,34,331 (£10,100) in 1932. The most valuable of these materials is kyanite extracted for export by the Indian Copper Corporation from Lopso Hill in Kharsawan.

TABLE 44.—*Quantity and value of Miscellaneous Refractory Materials produced in Bihar and Orissa during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| Kyanite | (a) 3,412 | 48,928 | 3,624 | 5,555 | 90,852 | 6,831 |
| Quartz-mica schist | 1,544 | 8,589 | 636 | 2,389 | 31,098 | 2,338 |
| Quartzite | 4,760 | 11,446 | 848 | 6,204 | 12,381 | 931 |
| TOTAL | 9,716 | *68,963* | *5,108* | 14,148 | *1,34,331* | *10,100* |

(a) Includes 3 tons of Kyanite produced in Ajmer-Merwara, Rajputana

**Ochre.**

There was an increase in the production of ochre from 4,951 tons, valued at Rs. 25,895 (£1,918) in 1931, to 6,237 tons valued at Rs. 33,110 (£2,489) in 1932. This increase is mainly due to Central India, and the Central Provinces, the two largest producers.

TABLE 45.—*Quantity and value of Ochre produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5) | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons | Rs | £ | Tons | Rs. | £ |
| Central India | 864 | 3,360 | 249 | 1,857 | 15,274 | 1,148 |
| Central Provinces | 2,828 | 11,693 | 866 | 3,365 | 9,747 | 733 |
| Gwalior | 567 | 5,656 | 419 | 403 | 3,277 | 246 |
| Madras | 300 | 3,550 | 263 | 300 | 3,550 | 267 |
| Rajputana | 312 | 1,076 | 80 | 312 | 1,262 | 95 |
| United Provinces | 80 | 560 | 41 | .. | .. | .. |
| TOTAL | 4,951 | *25,895* | *1,918* | 6,237 | *33,110* | *2,489* |

**Pyrite.**

There was an output of 23 tons of pyrite in Patiala State, Punjab, in 1930. The value was not reported. There was no recorded output in 1931 and 1932.

**Serpentine.**

The figures of production of serpentine in the Skardu *tahsil*, Kashmir State, amounting to 1·8 tons valued at Rs. 75 (£6) reported for 1930, were identical with those for 1929 and 1928. The same value has been recorded in 1931, but the quantity produced has not been stated. No report has been received for 1932.

**Soda.**

A production of 14·7 tons of soda valued at Rs. 533 (£39) was reported from the Ladakh *tahsil*, Kashmir State, in both 1929 and 1930. The output reported for 1928 was 11 tons valued at Rs. 533 (£40), in 1931

11 tons valued at Rs. 412 (£31), and in 1932, also, 11 tons valued at Rs. 435 (£33). Salt, consisting for the greater part of sodium carbonate, sodium bicarbonate and sodium chloride, used to be obtained by evaporation from the waters of the Lonar Lake, in the Buldana district of Berar, in the Central Provinces. It was known under the general name of *trona* or *urao*, for which there is no suitable equivalent in English. The total amount of *trona* extracted in 1926 was 100 tons, the value of which was estimated at Rs. 3,000 (£224); as the company working the concession went into liquidation there has been no further reported production until 1930, for which the output was 100 tons valued at Rs. 950 (£70). There was no production in 1931.

Steatite.

There was an increase in the production of steatite, which rose from 5,135 tons valued at Rs. 1,21,508 (£9,001) in 1931, to 6,512 tons valued at Rs. 1,29,490 (£9,736) in 1932. This rise was mainly due to the Jaipur State, now responsible for some 80 per cent. of the total Indian output.

TABLE 46.—*Quantity and value of Steatite produced in India during the years 1931 and 1932.*

| — | 1931. | | | 1932. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value (£1 = Rs. 13·5). | | Quantity. | Value (£1 = Rs. 13·3). | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Bihar and Orissa*— Mayurbhanj State | 27 | 2,600 | 193 | .. | .. | .. |
| Seraikela State | 37 | 1,000 | 74 | .. | .. | .. |
| Singhbhum | 442 | 7,746 | 574 | 152 | 760 | 57 |
| *Central India*— Bijawar State | 74 | 1,200 | 89 | 119 | 2,430 | 183 |
| *Central Provinces*— Jubbulpore | 188 | 4,077 | 302 | 402 | 9,480 | 713 |
| *Madras*— Nellore | 50 | 1,000 | 74 | 41 | 1,909 | 143 |
| Salem | 147 | 3,075 | 228 | 179 | 2,855 | 215 |
| *Mysore State* | 79 | 574 | 43 | 133 | 542 | 41 |
| *Rajputana*— Ajmer-Merwara | 25 | 169 | 12 | .. | .. | .. |
| Jaipur State | 3,915 | 93,884 | 6,954 | 5,172 | 1,07,220 | 8,061 |
| *United Provinces*— Hamirpur | 151 | 6,183 | 458 | 314 | 4,294 | 323 |
| TOTAL | 5,135 | *1,21,508* | *9,001* | 6,512 | *1,29,490* | *9,736* |

Sulphate of ammonia.

Until recently, figures of production of ammonium sulphate as a bye-product at the coking plants of iron and steel works and collieries have been collected only every five years for the quinquennial reviews of mineral production. They prove, however, to be of such general interest that it has been thought desirable to report them annually, and the figures for 1931 and 1932 are shown in Table 47. Values have not been obtained, and ammonium sulphate will not therefore find a place in Table 1. The figures show a decrease in production from 12,133 tons in 1931, to 9,474 tons in 1932. The exports for these two years were 3,051 and 303 tons respectively. The cessation of production by four producers is due to the low price of ammonium sulphate.

TABLE 47.—*Production of Sulphate of Ammonia in India during the years 1931 and 1932.*

| — | 1931. | 1932. |
|---|---|---|
| | Tons. | Tons. |
| The Bengal Iron Co., Ltd. | 718 | .. |
| The Oriental Gas Co., Ltd. | 132 | .. |
| The Eastern Coal Co., Ltd. | 279 | .. |
| The Tata Iron and Steel Co., Ltd. | 5,701 | 5,304 |
| The Indian Iron and Steel Co., Ltd. | 2,155 | 2,271 |
| The Lodna Colliery Co. (1920), Ltd. | 392 | .. |
| The Burrakur Coal Co., Ltd. | 1,291 | 736 |
| The East Indian Railway Colliery, Giridih | 270 | 253 |
| The Bararee Coke Co., Ltd. | 1,195 | 910 |
| TOTAL | **12,133** | **9,474** |

## IV.—MINERAL CONCESSIONS GRANTED.

TABLE 48.—*Statement of Mineral Concessions granted during the year 1932.*

### AJMER-MERWARA.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Ajmer . . | (1) Mr. L. Prag Narain, Ajmer. | Iron and copper . | P. L. . | 7·2 | 5th January 1932. | 1 year. |
| Do. . . | (2) Messrs. Abdul Ghani & Co., Nasirabad. | Mica . . . . | P. L. . | 2·8 | 29th June 1932. | Do. |
| Do. . . | (3) Mr. L. Prag Narain, Ajmer. | Beryl and felspar . | P. L. . | 0·8 | 10th August 1932. | Do. |
| Do. . . | (4) Do. . | Asbestos and greenstone. | P. L. . | 18·4 | 16th November 1932. | Do. |
| Do. . . | (5) Do. . | Kaolin, mica, felspar, greenstone, muscovite, garnet and beryl-ore. | M. L. . | 4·4 | 30th April 1932. | 3 years. |
| Do. . . | (6) Do. . | Kaolin . . . . | M. L. . | 4·2 | 11th January 1932. | 10 years. |
| Do. . . | (7) Mr. L. Goverdhan Lal Rathi, Nasirabad. | Mica . . . . | M. L. . | Whole of Shokhia village. | 10th December 1932. | 5 years. |
| Beawar . | (8) Mr. L. Prag Narain, Ajmer. | Asbestos and soapstone. | P. L. . | 3·6 | 15th January 1932. | 6 months. |
| Do. . | (9) Do. . | Red and yellow ochres. | P. L. . | 1·6 | 5th October 1932. | 1 year. |

### ASSAM.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Cachar . | (10) Messrs. The Burmah Oil Co., Ltd. | Natural petroleum . | P. L. . | 1,088·0 | 3rd December 1932. | 1 year. |
| Do. . | (11) Do. . | Do. . | P. L. . | 3,001·6 | 12th April 1932. | Do. |
| Do. . | (12) Do. . | Do. . | P. L. . | 2,060·8 | 1st June 1932 | Do. |
| Lakhimpur . | (13) Messrs. The Assam Oil Co., Ltd. | Petroleum . . | P. L. . | 5,120·0 | 30th March 1932. | Do. |
| Do. . | (14) Do. . | Do. . . | P. L. . | 3,968·0 | 12th May 1932. | Do. |
| Do. . | (15) Do. . | Do. . . | P. L. . | 1,792·0 | 25th October 1931. | Until such time as a Mining Lease is granted. |
| Do. . | (16) Do. . | Do. . . | P. L. . | 665·6 | 1st May 1932. | Do. |
| Do. . | (17) Do. . | Coal . . . | P. L. . | 1,190·4 | 8th October 1932. | 1 year. |

P. L.—*Prospecting License.* M. L.—*Mining Lease.*

## ASSAM—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Luchmipur . | (18) Messrs. The Assam Oil Co., Ltd. | Petroleum . . | P. L. . | 590·7 | 31st December 1932. | 1 year. |
| Do. . | (19) Do. . | Do. . . | P. L. . | 3,475·2 | Do. . | Until such time as a Mining Lease is granted. |
| Do. . | (20) Assam Railways and Trading Co., Ltd. | Coal . . . | M. L. . | 2,560·0 | 30th July 1931. | 30 years. |
| Sylhet . | (21) Messrs. The Burmah Oil Co., Ltd. | Mineral oil . . | P. L. . | 3,136·0 | 3rd May 1932 | 1 year. |
| Do. . | (22) Do. . | Do. . . | P. L. . | 3,161·6 | 3rd September 1932. | Do. |
| Do. . | (23) Do. . | Do. . . | P. L. . | 9,305·6 | 1st October 1932. | Do. |

## BALUCHISTAN.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Quetta-Pishin | (24) Malik Abdul Aziz Yasinzai, Hanna Village, Quetta. | Coal . . . | M. L. . | 320 | 1st July 1932 | 30 years. |
| Do. . | (25) Do. . | Do. . . . | M. L. . | 320 | Do. . | Do. |
| Do. . | (26) Do. . | Do. . . . | M. L. . | 320 | Do. . | Do. |

## BENGAL.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Chittagong . | (27) Messrs. The Burmah Oil Co., Ltd. | Natural petroleum . | P. L. . (Renewal). | 4,000 | 9th March 1932. | 1 year. |

## BIHAR AND ORISSA.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Angul . . | (28) Babu Raja Tricumji. | Ochre . . . | P. L. . | 640·0 | 1st January 1932. | 1 year. |
| Singhbhum . | (29) Babu Dhanji Kumerji. | Iron-ore and manganese. | M. L. . | 500·0 | 2nd April 1932. | 10 years. |
| Do. . | (30) Babu Narendra Nath Kumar. | Chromite . . | M. L. . | 356·5 | 28th April 1932. | Up to 30th June 1939. |
| Do. . | (31) Babu Ajit Kumar Mullick. | Do. . . | P. L. . | 408·0 | 27th August 1932. | 6 months. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

## BOMBAY.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Kanara | (32) Messrs. Boyce and Company, Belgaum. | Manganese-ore | M. L. | 28 | 21st June 1932. | 10 years. |
| Do. | (33) Messrs. Killick Nixon & Co., Bombay. | Do. | M. L. | 80 | 28th September 1932. | Do. |
| Ratnagiri | (34) Messrs. Oakley, Dunan & Co., Ltd. | Chromite | M. L. | 172 | 4th March 1932. | Do. |
| Do. | (35) Do. | Do. | P. L. | 1,280 | 1st January 1932 | 1 year. |

## BURMA.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Akyab | (36) Messrs. The Burmah Oil Co., Ltd. | Natural petroleum (including natural gas). | P. L. | 4,480·0 | 28th July 1931 | 1 year 8 months 4 days. |
| Do. | (37) Do. | Do. | P. L. | 1,164·8 | 15th February 1932. | 2 years. |
| Do. | (38) Messrs. The Indo-Burma Petroleum Co., Ltd. | Do. | P. L. | 5,440·0 | 15th December 1931. | Do. |
| Do. | (39) Do. | Do. | P. L. | 1,180·0 | 22nd April 1931. | Do. |
| Do. | (40) Messrs. The Burmah Oil Co., Ltd. | Do. | P. L. | 5,056·0 | 9th May 1932 | Do. |
| Do. | (41) Do. | Do. | P. L. | 4,352·0 | 9th May 1932 | Do. |
| Do. | (42) Do. | Do. | P. L. | 633·6 | 30th July 1932. | Do. |
| Do. | (43) Do. | Do. | P. L. (Renewal). | 2,944·0 | 18th April 1932. | 1 year. |
| Amherst | (44) U On Pe | All minerals except oil. | P. L. (Renewal). | 640·0 | 5th February 1932. | Do. |
| Lower Chindwin. | (45) Mr. Lawrence Dawson. | Natural petroleum (including natural gas). | P. L. | 1,196·8 | 5th February 1931. | 2 years. |
| Do. | (46) Messrs. The Indo-Burma Petroleum Co., Ltd. | Do. | P. L. | 3,187·2 | 24th September 1931. | Do. |
| Do. | (47) Do. | Do. | P. L. | 829·0 | 30th July 1932. | Do. |
| Do. | (48) Do. | Do. | P. L. (Renewal). | 5,760·0 | 5th July 1932 | 1 year. |
| Magwe | (49) Do. | Do. | P. L. (Renewal) | 320·0 | 16th April 1931. | Do. |
| Do. | (50) Messrs. The British Burma Petroleum Co., Ltd. | Do. | P. L. (Renewal). | 15,360·0 | 11th April 1932. | Do. |
| Do. | (51) Do. | Do. | P. L. (Renewal). | 640·0 | 20th April 1932. | Do. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

## BURMA—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Magwe . | (52) Messrs. The Indo-Burma Petroleum Co., Ltd. | Natural petroleum (including natural gas). | P. L. . (Renewal). | 320·0 | 16th April 1932. | 1 year. |
| Do. . | (53) U Maung Gale . | Do. . | P. L. . (Renewal). | 320·0 | 7th April 1932. | Do. |
| Mergui . | (54) Mr. Lim Oo Ghine | Tin and allied minerals. | P. L. . | 1,113·6 | 18th January 1932. | Do. |
| Do. . | (55) Mr. Kapur Singh | Tin-ore . . . | P. L. . | 889·6 | 7th May 1932 | Do. |
| Do. . | (56) Mr. B. P. O. Watson. | Tin and allied minerals. | P. L. . | 243·2 | 8th January 1932. | Do. |
| Do. . | (57) Maung Hline Pu . | Do. . | P. L. . | 153·6 | 1st July 1932 | Do. |
| Do. . | (58) Maung Sein Shan. | Do. . | P. L. . | 384·0 | 17th March 1932. | Do. |
| Do. . | (59) Mr. Udhandas . | Do. . | P. L. . | 646·4 | 16th August 1932. | Do. |
| Do. . | (60) Maung Po Thaik . | Tin and wolfram . | P. L. . | 486·4 | 2nd February 1932. | Do. |
| Do. . | (61) U E Gyi . . | Tin and allied minerals. | P. L. | 204·8 | 19th March 1932. | Do. |
| Do. . | (62) Mr. A. E. Ahmed. | Tin-ore and other allied minerals. | P. L. . | 358·4 | 18th March 1932. | Do. |
| Do. . . | (63) Messrs. The Malayan and General Trust Ltd. | Tin . . . | P. L. . | 179·2 | 25th July 1932. | Do. |
| Do. . . | (64) Mr. Saw Lein Lee | Tin and allied minerals. | P. L. . | 64·0 | 26th June 1932. | Do. |
| Do. . . | (65) Mr. Eu Gwan Kyin | Do. . | P. L. . | 691·2 | 15th September 1932. | Do. |
| Do. . . | (66) Mr. Eu Gwan Kyin | Do. . | P. L. . | 51·2 | 25th April 1932. | Do. |
| Do. . . | (67) Mr. Neil Gow . | Tin-ore . . . | P. L. . | 1,587·2 | 4th November 1932. | Do. |
| Do. . . | (68) Maung San Dun . | Tin and allied minerals. | P. L. . | 140·8 | 11th May 1932. | Do. |
| Do. . . | (69) Maung Hline Pu . | Do. . | P. L. . | 230·4 | 1st July 1932. | Do. |
| Do. . . | (70) Mr. Leong Foke Hye. | Tin, wolfram and other allied minerals. | P. L. . | 345·6 | 12th March 1932. | Do. |
| Do. . . | (71) Mr. F. Wah Yu . | Tin and allied minerals. | P. L. . | 480·0 | 17th March 1932. | Do. |
| Do. . . | (72) Maung San Dun . | Tin . . . | P. L. . | 614·4 | 18th June 1932. | Do. |
| Do. . . | (73) Mr. Leong Foke Hye. | Tin, wolfram and other allied minerals. | P. L. . | 422·4 | 14th May 1932. | Do. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

## BURMA—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Mergui . | (74) Mr. Yew Shwe Ni. | Tin-ore and wolfram | P. L. . | 211·2 | 9th July 1932. | 1 year. |
| Do. . . | (75) Mr. Eng Tain Leong. | Tin and allied minerals. | P. L . | 192·0 | 26th March 1932. | Do. |
| Do. . . | (76) Mr. Leong Foke Hye. | Tin and wolfram . | P. L. . | 384·0 | 18th April 1932. | Do. |
| Do. . . | (77) Maung San Dun . | Tin and allied minerals. | P. L. . | 486·4 | 11th April 1932. | Do. |
| Do. . . | (78) Maung San Dun . | Tin . . . | P. L. . | 128·0 | 10th November 1932. | Do. |
| Do. . . | (79) Maung Hline Pu . | Tin and allied minerals. | P. L. . | 358·4 | 13th July 1932. | Do. |
| Do. . . | (80) Mr. Balwant Singh | Tin . . . | P. L. . | 563·2 | 17th November 1932. | Do. |
| Do. . . | (81) Mr. M. Haniff . | Tin-ore and other allied minerals. | P. L. . | 243·2 | 1st July 1932. | Do. |
| Do. . . | (82) Mr. Ah Khoon . | Tin-ore . . . | P. L. . | 76·8 | 26th September 1932. | Do. |
| Do. . . | (83) Mr. E. Maxwell Lefroy. | All minerals except oil and precious stones. | P. L. . | 44·8 | 26th July 1932. | Do. |
| Do. . . | (84) Mr. Tan Aik Kun | Tin and allied minerals. | P. L. . | 230·4 | 26th October 1932. | Do. |
| Do. . . | (85) Mr. J. T. Doupe . | Do. . | P. L. . | 486·4 | 9th September 1932. | Do. |
| Do. . . | (86) Maung Po Thaik . | Tin . . . | P. L. . | 615·4 | 10th August 1932. | Do. |
| Do. . . | (87) Mr. Udhandas . | Tin and allied minerals. | P. L. . | 422·4 | 14th September 1932. | Do. |
| Do. . . | (88) Maung Hline Pu . | Do. . | P. L. . | 313·6 | 30th November 1932. | Do. |
| Do. . . | (89) Mr. Tan Boon Hein | Tin-ore . . . | P. L. . | 102·4 | 4th November 1932. | Do. |
| Do. . . | (90) Mr. J. T. Doupe . | Tin and all other minerals except oil. | P. L. . | 1,164·8 | 24th October 1932. | Do. |
| Do. . . | (91) Maung San Dun . | Tin . . . | P. L. . | 576·0 | 19th December 1932. | Do. |
| Do. . . | (92) U E Gyi . . | Tin and allied minerals. | P. L. . | 64·0 | 25th November 1932. | Do. |
| Do. . . | (93) Maung Po Thaik . | Tin . . . | P. L. . | 243·2 | 19th November 1932. | Do. |
| Do. . . | (94) Mr. Gul Mahamed | All minerals except mineral oil. | P. L. . | 76·8 | 1st November 1932. | Do. |
| Do. | (95) Messrs. L. W. Elsum and Chan Kee. | Do. . | P. L. . | 576·0 | 16th September 1932. | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## BURMA—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Mergui . | (96) Maung Sein Shan. | Tin . . . . | P. L. . | 396·8 | 25th November 1932. | 1 year |
| Do. . . | (97) Mr. Eng Tain Leong. | Do. . . . . | P. L. . | 179·2 | 29th October 1932. | Do. |
| Do. . . | (98) Mr In Sit Yan . | Tin and allied minerals. | P. L. . | 880 6 | 28th November 1932. | Do |
| Do. . . | (99) Messrs. The Burma Alluvials Syndicate, Ltd. | Tin . . . . | M. L. . | 460·8 | 15th June 1932. | 30 years. |
| Do. . . | (100) Mr. S H. Harman | Cassiterite and associated minerals. | M. L. . | 332·8 | 1st September 1932. | Do |
| Do . . | (101) Mr. Ah Shee . | Tin-ore . . . | M. L. . | 115·2 | 1st August 1932. | Do. |
| Do. . . | (102) Mr. Khoo Tun Byan. | Cassiterite or tin-ore | M. L. . | 230·4 | 1st December 1932. | Do. |
| Do . . | (103) Messrs. The Malayan and General Trust, Ltd. | Tin-ore . . . . | M. L. . | 179·2 | 15th November 1932. | Do |
| Do. . . | (104) Mr Ah Khoon . | Tin and allied minerals | P. L. . (Renewal). | 198·4 | 11th February 1932. | 1 year. |
| Do. . . | (105) Ma Tin . . | Do. . | P. L. . (Renewal). | 256·0 | 14th February 1932. | Do. |
| Do. . . | (106) Mr. G. H. Hand | Gold, tin and allied minerals. | P. L. . (Renewal). | 390·4 | 20th February 1932. | Do. |
| Do. . . | (107) Mr. Gul Mahamed | Tin and allied minerals. | P. L. . (Renewal) | 153·6 | 18th April 1932. | Do. |
| Do . . | (108) U E Gyi . . | Do. . | P. L. . (Renewal) | 128·0 | 22nd May 1932. | Do. |
| Do. . . | (109) Mr. Khoo Tun Byan. | Do. . | P. L. . (Renewal). | 108·4 | 20th May 1932. | Do. |
| Do. . . | (110) Mr. Ah Khoon . | Tin-ore . . . . | P. L. . (Renewal). | 102·4 | 15th August 1932. | Do. |
| Do. . . | (111) Mr. Khoo Tun Byan. | Tin and allied minerals. | P. L. . (Renewal). | 192·0 | 14th August 1932. | Do. |
| Do. . . | (112) Mr. E. B. Milne . | Tin . . . . | P. L. . (Renewal). | 172·8 | 24th August 1932. | Do. |
| Do . . | (113) Mr E. Ahmed . | Tin-ore and other allied minerals. | P. L. . (Renewal). | 275·2 | 25th August 1932. | Do. |
| Do. . . | (114) Mr. Eng Tain Leong. | Do. . | P. L. . (Renewal). | 7,680·0 | 18th September 1932. | Do. |
| Do. . . | (115) Mr. Udhandas . | Do. . | P. L. . (Renewal). | 550·4 | 21st September 1932. | Do. |
| Do. . . | (116) Do. . | Do. . | P. L. . (Renewal). | 211·2 | 14th September 1932. | Do. |
| Do. . . | (117) Mr. G. H. Hand | Gold, tin and allied minerals. | P. L. . (Renewal). | 268·8 | 19th September 1932. | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## BURMA—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Mergui . | (118) Saw Maung Po . | Tin . . . | P. L. (Renewal). | 230·4 | 11th September 1932. | 1 Year. |
| Do. . . | (119) Messrs. The Malayan and General Trust, Ltd. | Do. . . . | P. L. (Renewal). | 998·4 | 24th September 1932. | Do. |
| Minbu . | (120) Messrs. The Burmah Oil Co., Ltd. | Natural petroleum . | P. L. . | 80·0 | 10th May 1932. | Do. |
| Myingyan . | (121) Messrs. The Yenangyaung Oilfield Southern Extension, Ltd. | Natural petroleum (including natural gas). | P. L. . | 1,280·0 | 27th September 1932. | 2 years. |
| Myitkyina . | (122) Mr. J. T. O. Barnard. | Mica and other minerals. | P. L. . | 512·0 | 25th May 1932. | 1 year. |
| Northern Shan States. | (123) Mr. A. R. Oberlander. | Gold . . . | P. L. . | 640·0 | 7th December 1932. | Do. |
| Do. . | (124) Messrs. The Burma Corporation, Ltd. | All minerals . . | P. L. . | 1,440·0 | Do. . | Do. |
| Do. . | (125) Do. . | Do. . . | P. L. . | 1,330·0 | Do. . | Do. |
| Do. . | (126) Do. . | Do. . . | P. L. . | 480·0 | 9th August 1932. | Do. |
| Do. . | (127) Do. . | Iron-ore . . . | P. L. . | 88·4 | 6th March 1931. | 2 years. |
| Do. . | (128) Mr. A. R. Oberlander. | Lead and silver . | P. L. (Renewal). | 320·0 | 20th August 1932. | 6 months or until the M. L. is granted whichever is less. |
| Pakokku . | (129) U. Myat San . | Natural petroleum (including natural gas). | P. L. . | 102·4 | 19th August 1932. | 2 years. |
| Do. . | (130) Messrs. The Burmah Oil Co., Ltd. | Do. . | P. L. (Renewal). | 320·0 | 24th April 1932. | 1 year. |
| Do. . | (131) Do. . | Do. . | P. L. (Renewal). | 778·2 | 23rd December 1932. | Do. |
| Prome . | (132) Do. . | Do. . | P. L. . | 4,640·0 | 21st May 1932. | 2 years. |
| Shwebo . | (133) Messrs. The Indo-Burma Petroleum Co., Ltd. | Do. . | P. L. . | 2,547·2 | 12th March 1932. | Do. |
| Do. . | (134) Do. . | Do. . | P. L. . | 5,440·0 | 14th August 1932. | 1 year. |
| Southern Shan States. | (135) Mr. E. C. M. Garrett. | All minerals except mineral oil. | P. L. . | 761·6 | 8th July 1932 | Do. |
| Do. . | (136) Do. . | Do. . | P. L. . | 960·0 | 8th June 1932 | Do. |
| Do. . | (137) Messrs. The Shan States Silver Lead Corporation. | Do. . | P. L. . | 441·6 | 23rd September 1931. | 2 years. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

## BURMA—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Southern Shan States. | (138) Mr. E. C. M. Garrett. | All minerals except mineral oil. | P. L. . | 371·2 | 12th December 1932. | 1 year. |
| Do. . | (139) Mr. Syed Ebrahim. | Wolfram. . . | P. L. . | 640·0 | 8th April 1932 | Do. |
| Do. . | (140) Mr. Abdul Haq . | Do. . . | P. L. . (Renewal). | 640·0 | 3rd July 1932 | Do. |
| Tavoy . | (141) Mr. Teh Lu Pe . | Tin and wolfram . | P. L. . | 1,216·0 | 2nd January 1932. | Do. |
| Do. . | (142) Mr. Mohamed Gouse. | Do. . | P. L. . | 1,536·0 | 20th April 1932. | Do. |
| Do. . | (143) U. Ba Oh (2) . | Tin and allied minerals. | P. L. . | 768·0 | 23rd May 1932. | Do. |
| Do. . | (144) Mr. Teh Lu Pe . | Do. . | P. L. . | 627·2 | 10th February 1932. | Do. |
| Do. . | (145) U. Ohn Nyun . | Tin and wolfram . | P. L. . | 275·2 | 7th March 1932. | Do. |
| Do. . | (146) Mr. H. G. Gregson, Calcutta. | Do. . | P. L. . | 108·8 | 21st May 1932. | Do. |
| Do. . | (147) Mr. Chan Kee . | Do. . | P. L. . | 768·0 | 18th April 1932. | Do. |
| Do. . | (148) Mr. H. G. Gregson, Calcutta. | Do. . | P. L. . | 89·6 | 29th July 1932. | Do. |
| Do. . | (149) Do. . | Do. . | P. L. . | 70·4 | 17th June 1932. | Do. |
| Do. . | (150) Mr. Teh Lu Pe . | Do. . | P. L. . | 204·8 | 23rd May 1932. | Do. |
| Do. . | (151) U. Ba Oh (2) . | Do. . | P. L. . | 172·8 | 31st May 1932. | Do. |
| Do. . | (152) U. Ohn Nyun . | Do. . | P. L. . | 275·2 | 7th July 1932 | Do. |
| Do. . | (153) Mr. G. A. Tudu . | Do. . | P. L. . | 147·2 | 4th August 1932. | Do. |
| Do. . | (154) U. Ohn Nyun . | Do. . | P. L. . | 384·0 | 7th July 1932 | Do. |
| Do. . | (155) Mr. D. R. Bowrie | All minerals except oil. | P. L. . | 640·0 | 2nd July 1932 | Do. |
| Do. . | (156) Mr. H. G. Gregson, Calcutta. | Tin and wolfram . | P. L. . | 96·0 | 20th August 1932. | Do. |
| Do. . | (157) Mr. Teh Lu Pe . | Tin and allied minerals. | P. L. . | 486·4 | 14th July 1932. | Do. |
| Do. . | (158) Daw Thi . . | Tin and wolfram . | P. L. . | 832·0 | 27th July 1932. | Do. |
| Do. . | (159) Mr. Kim Swe . | Do. . | P. L. . | 588·8 | 22nd July 1932. | Do. |
| Do. . | (160) Mr. L. W. Elsum | All minerals except oil. | P. L. . | 224·0 | 17th August 1932. | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## BURMA—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Tavoy . | (161) Mr. Quah Hun Cheong. | All minerals except oil. | P. L. . | 1,574·4 | 17th December 1932. | 1 year. |
| Do. . | (162) Do. . | Do. . . | P. L. . | 396·8 | 22nd December 1932. | Do. |
| Do. | (163) Messrs. Eu Pola Brothers. | Tin and wolfram . | P. L. . | 211·2 | 30th November 1931. | Do. |
| Do. . | (164) Messrs. The Tavoy Tin Dredging Corporation, Ltd. | All minerals except oil. | M. L. . | 1,088·0 | 1st February 1930. | 30 years. |
| Do. . | (165) Do. . | Do. . . | M. L. . | 582·4 | 1st July 1932 | Do. |
| Do. . | (166) Messrs. The Anglo-Burma Tin Co., Ltd. | Do. . . | M. L. . | 89·6 | 18th April 1931 | Do. |
| Do. . | (167) Mr. Khoo Sein Shan. | Tin and wolfram . | M. L. . | 563·2 | 16th March 1932. | Do. |
| Do. . | (168) Messrs. The Consolidated Tin Mines of Burma Ltd. | Tin and tungsten-ore. | M. L. . | 320·0 | 1st January 1932. | Do. |
| Do. . | (169) Messrs. The Anglo-Burma Tin Co., Ltd. | Tin and allied minerals. | M. L. . | 2,080·0 | 1st September 1932. | Do. |
| Do. . | (170) U Ohn Nyun . | Do. . . | M. L. . | 185·6 | 15th November 1932 | Do. |
| Do. . | (171) Do. . . | Tin and wolfram . | P. L. (Renewal). | 768·0 | 29th September 1931. | 1 year. |
| Do. . | (172) U Ba Oh (2) . | Do. . . | P. L. (Renewal). | 70·4 | 14th November 1931. | Do. |
| Do. . | (173) Mr. J. M. Khan . | Do. . . | P. L. (Renewal). | 499·2 | 20th January 1932. | Do. |
| Do. . | (174) Mr. D. R. Bowrie | Do. . . | P. L. (Renewal). | 640·0 | 7th August 1932. | Do. |
| Do. . | (175) Mr. Quah Hun Cheong. | Do. . . | P. L. (Renewal). | 64·0 | 1st September 1932. | Do. |
| Do. . | (176) Mr. C. Soo Don . | Do. . . | P. L. (Renewal). | 147·2 | 24th October 1932. | Do. |
| Thaton . | (177) Mr. B. B. Fernandez. | All minerals except oil. | P. L. . | 486·4 | 17th June 1932. | Do. |
| Do. . | (178) Maung Nyun U . | Do. . . | P. L. (Renewal). | 40·0 | 11th January 1932. | Do. |
| Thayetmyo . | (179) Messrs. The Indo-Burma Petroleum Co., Ltd., Rangoon. | Natural petroleum (including natural gas). | P. L. . | 3,840·0 | 9th September 1932. | 2 years. |
| Do. . | (180) Do. . . | Do. . . | M. L. . | 2,400·0 | 1st September 1932. | 30 years. |
| Do. . | (181) Mr. W. R. Smith, Rangoon. | Do. . . | P. L. (Renewal). | 441·6 | 16th August 1932. | 1 year |
| Do. . | (182) Messrs. The Burmah Oil Co., Ltd. | Do. . . | P. L. (Renewal). | 2,457·6 | 30th June 1932 | Do. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

## BURMA—*concld.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Thayetmyo . | (183) Messrs. The Burmah Oil Co., Ltd. | Natural petroleum (including natural gas). | P. L. . (Renewal). | 1,984·0 | 16th November 1932. | 1 year. |
| Upper Chindwin. | (184) Messrs. Fairweather Richards & Co., Ltd., Rangoon. | Coal . . . . | P. L. . | 704·0 | 11th March 1932. | Do. |
| Do. . | (185) Do. . . | Do. . . . . | P. L. . | 568·2 | 15th August 1932. | Do. |
| Do. . | (186) Messrs. The Indo-Burma Petroleum Co., Ltd., Rangoon. | Natural petroleum (including natural gas). | P. L. . | 1,419·5 | 17th March 1932. | 2 years. |
| Do. . | (187) Messrs. The Burmah Oil Co., Ltd., Rangoon. | Do. . . | P. L. . (Renewal). | 8,320·0 | 25th June 1932. | 1 year. |
| Do. . | (188) Messrs. The Indo-Burma Petroleum Co., Ltd., Rangoon. | Do. . . | P. L. . (Renewal). | 2,880·0 | 2nd August 1932. | Do. |
| Do. . | (189) Do. . | Do. . . | P. L. . (Renewal). | 640·0 | 6th October 1932. | Do. |
| Yamethin . | (190) Hajee Makatiza Bibi. | Galena or lead-ore . | P. L. . | 640·0 | 29th March 1932. | Do. |

## CENTRAL PROVINCES.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Balaghat . | (191) Mr. Kanhiyalal, Balaghat. | Manganese . . | M. L. . | 194 | 5th April 1932 | 10 years. |
| Do. . | (192) Messrs. B. P. Byramji & Co., Nagpur. | Do. . . . . | M. L. . | 2 | 9th November 1931. | 5 years. |
| Do. . | (193) Thakur Nasibsingh, Bijagarh. | Do. . . . . | M. L. . | 7 | 17th November 1931. | 15 years. |
| Do. . | (194) Messrs. B. P. Byramji & Co., Nagpur. | Do. . . . . | M. L. . | 322 | 28th January 1932. | 5 years. |
| Betul . . | (195) Messrs. F. L. G. Simpson and Seth Misrilal Meghraj. | All minerals . . | P. L . | 283 | 5th February 1932. | 1 year. |
| Bhandara . | (196) Messrs. B. Fouzdar Brothers, Nagpur. | Manganese-ore . | P. L. . | 16 | 17th March 1932. | Do. |
| Do. . | (197) Do. . . | Do. . . | P. L. . | 7 | Do. . | Do. |
| Do. . | (198) Mr. Ganpatrao Laxmanrao, Nagpur. | Flooring stone . | P. L. . | 11 | 22nd August 1932. | Do. |
| Do. . | (199) Messrs Harischandra and Bhadulal of Tumsar. | Manganese-ore . | M. L. . | 9 | 5th May 1932 | 10 years. |
| Bilaspur . | (200) Messrs. Gurudattsingh Mangalchand. | Limestone . . | Q. L. . | 15 | 27th October 1931. | Do. |
| Do. . | (201) The Tata Iron and Steel Co., Ltd. | Do. . . . . | Q. L. . | 98 | 14th January 1931. | Do. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.* Q. L. = *Quarry Lease.*

F

## CENTRAL PROVINCES—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Bilaspur . | (202) Messrs. Sheodyal Sawhney & Co., The ..Punjab Stone and Lime Factory. | Limestone . . | Q. L. . | 20 | 9th January 1932. | 10 years. |
| Do. . . | (203) Messrs. Gurubaxsingh Uttamsingh, contractors of Torwan. | Do. . . . | Q. L. . | 24 | 29th July 1932 | Do. |
| Do. . | (204) Asaram, son of Durjan, Mahar. | Clay . . . | Q. L. . | 2 | 5th August 1932. | 2 years. |
| Do. . | (205) Mangal, son of Puranik, Kahar. | Do. . . . | Q. L. . | 1 | Do. . | 5 years. |
| Do. . | (206) Messrs. Nanakchand Bhuwanmal Chhattri, contractors. | Do. . . . | Q. L. . | 2 | 22nd August 1932. | 1 year. |
| Do. . | (207) Messrs. Gurudattmal Kashiram & Co., contractors. | Do. . . . | Q. L. . | 4 | 15th November 1932. | 5 years. |
| Do. . | (208) Dharma, son of Jiwania, Mahar. | Do. . . . | Q. L. . | 1 | 17th November 1932. | 2 years. |
| Do. . | (209) Messrs. Dunlop and Considine, Ghordewa Coal Fields, Ltd. | Do. . . . | P. L. . | 10,297 | 8th April 1932 | 1 year. |
| Chanda . | (210) The firm of Dewan Bahadur Ballabhdas, Manoolal and Kanhaiyalal of Jubbulpore. | Do. . . . | Supplementary agreement to M. L. | 9 | 19th September 1932. | 16 years. |
| Do. . | (211) Messrs. Hasambhoy & Sons, General Merchant, Chanda. | Ochre . . . | P. L. . | 225 | 27th July 1932 | 1 year. |
| Do. . | (212) Mr. V. S. Phadke, Managing Director, The Central Potteries, Limited, Nagpur. | White clay . . | Q. L. . | 5 | 20th February 1932. | 10 years. |
| Chhindwara . | (213) Mr. J. N. Mazumdar. | Limestone . . | Q. L. . | 2 | 5th August 1932. | 10 years. |
| Do. . | (214) The Hirdagarh Collieries, Ltd. | Coal . . . | M. L. . | 165 | 25th April 1932 | 18 years. |
| Do. . | (215) Messrs. S. C. Cambata & Co. | Do. . . | P. L. . | 252 | 11th January 1932. | 1 year. |
| Do. . | (216) Do. . | Do. . . . | P. L. . | 485 | Do . | Do. |
| Do. . | (217) Do. . | Do. . . . | P. L. . | 479 | Do. . | Do. |
| Do. . | (218) Haji Syed Zahiruddin of Cawnpore. | Do. . . . | P. L. . | 423 | 16th February 1932. | Do. |
| Do. . | (219) Lala Budhoolal of Ghorawori. | Do. . . . | P. L. . | 148 | 9th April 1932 | Do. |
| Do. . | (220) Messrs. S. C. Cambata & Co. | Do. . . | P. L. . | (Not given) Entire village. | 19th May 1932 | Do. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.* Q. L. = *Quarry Lease.*

## CENTRAL PROVINCES—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Chhindwara | (221) Haji Syed Zahiruddin of Cawnpore. | Limestone | P. L. | 195 | 8th July 1932 | 1 year. |
| Do. | (222) The Central Provinces Contracting and Mining Syndicate. | Do. | P. L. | 242 | 10th August 1932. | Do. |
| Do. | (223) The Amalgamated Coal Field Ltd. | Do. | P. L. | 217 | 2nd September 1932. | Do. |
| Do. | (224) Messrs. Mangal Singh Ishwar Singh. | Do. | P. L. | 267 | 6th September 1932. | Do. |
| Do. | (225) Do. | Do. | P. L. | 701 | Do. | Do. |
| Do. | (226) Lala Budhoolal | Do. | P. L. | 441 | 24th November 1932. | Do. |
| Do. | (227) Do. | Do. | P. L. | 387 | Do. | Do. |
| Do. | (228) Do. | Do. | P. L. | 282 | Do. | Do. |
| Jubbulpore | (229) Katni Cement and Industrial Co., Ltd. | Clay | Q. L. | 7 | 25th January 1932. | 10 years. |
| Do. | (230) Pandit Chakorilal Pathak. | Bauxite | M. L. | 1 | 25th February 1932. | Do. |
| Do. | (231) Messrs. Dyers Stone Lime Co., Ltd. | Limestone | Q. L. | 21 | 1st January 1932. | Do. |
| Do. | (232) Mr. Nassarwanji Maneckji, Dubash. | Do. | Q. L. | 14 | 6th February 1932. | Do. |
| Do. | (233) Messrs. Ramchand Badri Parshad. | Do. | Q. L. | 5 | 4th September 1932. | Do. |
| Do. | (234) Seth Gangadhar Rameshwardass. | Fine clay | P. L. | 51 | 12th June 1932 | 1 year. |
| Do. | (235) Messrs. Shri Onama Glass Works. | Sand | Q. L. | 1 | 27th June 1932 | 10 years. |
| Do. | (236) Pandit Chakorilal Pathak. | Bauxite | M. L. | 1 | 20th July 1932 | 6½ years. |
| Do. | (237) Do. | Limestone | Q. L. | 8 | 25th February 1932. | 10 years. |
| Do. | (238) Do. | Bauxite | P. L. | 5 | 4th May 1932 | 1 year. |
| Do. | (239) Mr. Bansarup Sharma. | Limestone | Q. L. | 4 | 23rd February 1932. | 10 years. |
| Do. | (240) Do. | Do. | Q. L. | 2 | Do. | Do. |
| Do. | (241) Messrs. Burn & Co., Ltd. | Clay | Q. L. | 40 | 1st May 1932. | Do. |
| Do. | (242) Mr. Nassarwanji Maneckji, Dubash. | Limestone | Q. L. | 4 | 18th August 1932. | Do. |
| Do. | (243) Pandit Chakorilal Pathak. | Bauxite | P. L. | 3 | 22nd August 1932. | 1 year. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.* Q. L. = *Quarry Lease.*

## CENTRAL PROVINCES—*concld.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Jubbulpore . | (244) Mr. Nassarwanji Maneckji, Dubash. | Limestone . . | Q. L. . | 4 | 26th November 1932. | 10 years. |
| Nagpur . | (245) Messrs. Resham, son of Durga and Devideen, son of Laxman, Kumbhar. | Clay . . . | Q. L. . | 1 | 23rd November 1931. | Do. |
| Do. . | (246) Mr. M. A. Razaq. | Manganese-ore . | M. L. . | 114 | 1st December 1931. | Do. |
| Do. . | (247) Messrs. Buchya, son of Ganesha and Upashya, son of Govinda, Mahars. | Clay . . . | Q. L. . | 1 | 1st February 1932. | 5 years. |
| Do. . | (248) Messrs. Oke Brothers. | Building stone, laterite and clay. | Q. L. . | 9 | 29th June 1932 | 10 years. |
| Do. . | (249) Mr. Shamji Naranji. | Manganese-ore . | M. L.. . | 1 | 2nd July 1932 | 4 years. |
| Raipur . | (250) Messrs. S. C. Bose & Co., Contractors, Raipur. | Flagstones . . | P. L. . | 23 | 13th June 1932 | 1 year. |
| Do. . | (251) Do. | Clay . . . | P. L. . | 24 | 20th December 1932. | Do. |
| Do. . | (252) Rai Bahadur Dau Kalyansingh, Tahutdar of Tarenga. | Building stones . | Q. L. . | 18 | 8th July 1932. | 5 years. |
| Yeotmal . | (253) Ganpatrao Laxmanrao. | Limestone . . | P. L. . | 38 | 14th June 1932 | 1 year. |
| Do. . | (254) Do. . | Do. . . . | P. L. . | 8 | Do. . | Do. |
| Do. . | (255) Mr. M. D'Costa | Do. . . . | P. L. . | 27 | 15th October 1932. | Do. |

## MADRAS.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Anantapur . | (256) M. Rajagopala Nayudu. | Barytes . . . | M. L. . | 49·95 | 30th November 1932. | 10 years. |
| Chingleput . | (257) Messrs. Parry & Co., Ltd., Madras. | White clay . . | M. L. . | 0·95 | 1st April 1932 | Do. |
| Do. . | (258) M. R. Ry. Rao Sahib A. K. Ranganathan, Fngineering Contractor. | Limestone . . | M. L. . | 452·60 (effective operation in 125·82 acres only) | 7th August 1932. | 5 years. |
| Do. . | (259) President, District Board, Chingleput. | Metal and gravel . | M. L. . | 6·95 | 1st August 1931. | Do. |
| Do. . | (260) M. R. Ry. B. P. Sesha Reddi. | Steatite . . | M. L. . | 64·31 | 25th May 1932 | 30 years. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.* Q. L. = *Quarry Lease.*

## MADRAS—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Chingleput—*contd.* | (261) M. R. Ry. G. Singarayya Chetti. | Barytes . . . | P. L. . | 1·90 | 25th November 1932. | 1 year |
| Do. . | (262) Do. . | Do. . . . | P. L. . | 1·02 | Do. . | Do. |
| Do. . | (263) Khan Sahib K. Abdul Hye. | Do. . . . | P. L. . | 59·00 | 8th March 1932. | Do. |
| Do. . | (264) M. R. Ry. B. P. Sesha Reddi. | Do. . . . | P. L. . | 15·30 | 24th February 1932. | Do. |
| Do. . | (265) Do. . | Do. . . . | P. L. . | 4·83 | 26th February 1932. | Do. |
| Do. . | (266) Do. . | Do. . . . | P. L. . | 13·80 | 26th March 1932. | Do. |
| Do. . | (267) Do. . | Do. . . . | P. L. . | 4·66 | 27th February 1932. | Do. |
| Do. . | (268) M. R. Ry. V. Venkatasubbayya. | Barytes, iron-ore and manganese. | P. L. . | 80·20 | 12th February 1932. | Do. |
| Do. . | (269) M. R. Ry. B. P. Sesha Reddi. | Barytes . . . | P. L. . | 24·00 | 5th March 1932 | Do. |
| Do. . | (270) Do. . | Do. . . . | P. L. . | 4·80 | 22nd April 1932. | Do. |
| Do. . | (271) Do. . | Do. . . . | P. L. . | 7·60 | 22nd April 1932. | Do. |
| Do. . | (272) Janab Ashroff [Hussain Khan]. | Do. . . . | P. L. . | 30·00 | 5th April 1932 | Do. |
| Do. . | (273) Mandozie Janab Bapaji Abdul Nabi Sahib. | Do. . . . | P. L. . | 10·92 | 4th February 1932. | Do. |
| Do. . | (274) Do. . | Do. . . . | P. L. . | 47·22 | 22nd March 1932. | Do. |
| Do. . | (275) Do. . | Do. . . . | P. L. . | 45·26 | 21st March 1932. | Do. |
| Do. . | (276) Janab J. Yareen Khan Sahib. | Do. . . . | P. L. . | 4·84 | 1st October 1932. | Do. |
| Do. . | (277) Janab Bapari Abdul Nabi Sahib. | Do. . . . | P. L. . | 42·00 | 20th October 1932. | Do. |
| Do. . | (278) M. R. Ry. B. Venkataswami Chetti. | Do. . . . | P. L. . | 87·20 | 18th August 1932. | Do. |
| Do. . | (279) Do. . | Lead, zinc and barytes | P. L. . | 16·00 | 9th August 1932. | Do. |
| Do. . | (280) Do. . | Kaolin and yellow ochre. | P. L. . | 6·00 | 26th August 1932. | Do. |
| Do. . | (281) Do. . | China clay . . | P. L. . | 2·00 | 17th August 1932. | Do. |
| Do. . | (282) Do. . | Red oxide of iron . | P. L. . | 20·00 | 26th August 1932. | Do |
| Do. . | (283) Janab J. Yareen Khan Sahib. | Barytes . . . | P. L. . | 288·78 | 15th July 1932. | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## MADRAS—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Chingleput—*concld.* | (284) Janab Bepari Abdul Nabi Sahib. | Barytes | P. L. | 59·00 | 2nd September 1932. | 1 year. |
| Do. | (285) Janab Ashroff Hussain Khan Mandozie. | Do. | P. L. | 8·96 | 8th July 1932. | Do. |
| Do. | (286) Do. | Do. | P. L. | 28·07 | Do. | Do. |
| Do. | (287) Do. | Do. | P. L. | 12·00 | Do. | Do. |
| Do. | (288) M. R. Ry. B. P. Sesha Reddi. | Steatite | P. L. | 27·50 | 24th December 1932. | Do. |
| Do. | (289) Do. | Calcite | P. L. | 23·68 | 5th November 1932. | Do. |
| Do. | (290) Janab, J. Yareen Khan Sahib. | Barytes | P. L. | 106·00 | 25th November 1932. | Do. |
| Do. | (291) M. R. Ry. C. Manavalan. | Lead-ore. | P. L. | 2·18 | 5th December 1932. | Do. |
| Cuddapah | (292) Mr. S. S. Guzdar, Calcutta. | Barytes | P. L. | 4·80 | 23rd August 1932. | Do. |
| Do. | (293) M. R. Ry Bachu Venkatasubbyya. | China clay | M. L. | 6·94 | 1st July 1932. | 5 years. |
| Do. | (294) Messrs. D. Mohideen Sahib & Sons, Bellary. | Yellow ochre | M. L. | 8·00 | 29th November 1932. | Do. |
| Do. | (295) Mr. Muhammad Rahimthulla. | Asbestos | P. L. | 201·24 | 18th November 1931. | 1 Year. |
| Do. | (296) Mr. S. S. Guzdar | Do. | P. L. | 56·23 | 3rd June 1932 | Do. |
| Do. | (297) M. R. Ry. A. Kristnappa. | Barytes and yellow ochre | P. L. | 325·67 | 24th April 1932. | Do. |
| Do. | (298) Mr. S. S. Guzdar. | Barytes | P. L. | 26·50 | 23rd August 1932. | Do. |
| Do. | (299) M. R. Ry. G. K. Ramaswami Nayudu, Madras. | Galena | P. L. | 46·35 | 26th April 1932. | Do. |
| Do. | (300) Mr. Thomas Tiffin, Calcutta. | Barytes | P. L. | 39·65 | 7th December 1931. | Do. |
| Do. | (301) Mr. Abdul Hakeen, Calcutta. | Do. | P. L. | 109·00 | 14th March 1932. | Do. |
| Do. | (302) Mr. Thomas Tiffin | Do. | P. L. | 122·51 | 19th December 1931. | Do. |
| Nellore | (303) R. Venkatakrishnayya. | Mica | M. L. | 4·63 | 25th November 1931. | 30 years. |
| Do. | (304) C. Subbarami Reddi. | Do. | M. L. | 4·17 | 3rd December 1931. | Do. |
| Do. | (305) T. Venkatasubba Nayudu. | Do. | M. L. | 0·77 | 29th June 1932. | Do. |
| Do. | (306) C. Subbarami Reddi. | Do. | P. L. | 1·06 | 4th December 1931. | 1 year. |

P. L. = *Prospecting License*. M. L. = *Mining Lease*.

## MADRAS—*concld.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Nellore—*contd.* | (307) P. Venkayya . | Mica . . . . | P. L. . | 24·08 | 23rd March 1932. | 1 year. |
| Do. . | (308) P. Papi Reddi . | Do. . . . . | P. L. . | 15·50 | 15th July 1932. | Do. |
| Do. . | (309) P. Venkayya . | Do. . . . . | P. L. . | 68·53 | 17th September 1932. | Do. |
| Tinnevelly . | (310) Annavi Palpattina Nadar. | Garnet sand . . | M. L. . | 2·48 | 18th October 1932. | 5 years. |

## NORTH-WEST FRONTIER PROVINCE.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Bannu . | (311) Messrs. The Indo-Burma Petroleum Co., Ltd. | Natural petroleum (including natural gas). | P. L. . (Renewal) | 8,723·2 | 3rd February 1932. | 1 year. |
| Do. . | (312) Do. . | Do. . | P. L. . (Renewal). | 3,040 0 | 3rd August 1932. | Do. |
| Do. . | (313) Messrs. The Burmah oil Co., Ltd. | Do. . . | P. L. . (Renewal). | 13,248 0 | 2nd September 1932. | Do. |
| Dera Ismail Khan. | (314) Messrs. The Indo-Burma Petroleum Co., Ltd. | Mineral oil . . | P. L. . (Renewal). | 2,995·2 | 10th September 1932. | Do |
| Do. . | (315) Do. . | Natural petroleum (including natural gas). | P. L. . (Renewal). | 1,321·6 | 10th March 1932. | Do. |
| Do. . | (316) Messrs. The Attock oil Co., Ltd. | Mineral oil . . | P. L. . (Renewal). | 150·0 | 26th November 1932. | Do. |

## PUNJAB.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Attock. . | (317) Messrs. The Attock oil Co., Ltd. | Natural petroleum . | P. L. . | 1,053 0 | 19th November 1932. | 2 years. |
| Jhelum . | (318) Mr. L. Ram Lal. | Coal . . . . | M. L. . | 80 0 | 18th February 1930. | 15 years |
| Do. . | (319) Bhai Hazura Mal. | Do. . . | P. L. . | 68·8 | 1st February 1932. | 1 year. |
| Do. . | (320) Mr. L. Ishar Das Kapur. | Do. . . . | P. L. . | 63·0 | 31st August 1932. | Do. |
| Do. . | (321) Executors of the Estate of Late L. Shankar Das, Chuni Mundi, Lahore. | Do. . . . . | M. L. . | 755·0 | 20th August 1932. | 30 years. |
| Do. . | (322) Do. . | Do. . . . . | M. L. . | 455·5 | Do. . | Do. |
| Do. . | (323) Do. . | Do. . . . . | M. L. . | 1,016·2 | Do. . | Do. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

## PUNJAB—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Jhelum—*contd.* | (324) Mr. L. Charanjit Lal. | Coal . . . . | M. L. . | 54·5 | 1st October 1932. | 25 years. |
| Do. . | (325) Bhai Hazura Mal | Do. . . . . | P. L. . | 50·5 | 13th October 1932. | 1 year. |
| Do. . | (326) Mr. L. Sant Ram Kapur. | Do. . . . . | P. L. . | 72·8 | Do. . | Do. |
| Do. . | (327) Mr. L. Ishar Das Kapur. | Do. . . . . | P. L. . | 50·5 | 8th November 1932. | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## SUMMARY.

| Province. | Prospecting License. | Mining Lease | Quarry Lease. | Total of each Province. |
|---|---|---|---|---|
| Ajmer-Merwara . . . . . . . | 6 | 3 | .. | 9 |
| Assam . . . . . . . . . | 13 | 1 | .. | 14 |
| Baluchistan . . . . . . . . | .. | 3 | .. | 3 |
| Bengal . . . . . . . . . | 1 | .. | .. | 1 |
| Bihar and Orissa . . . . . . . | 2 | 2 | .. | 4 |
| Bombay . . . . . . . . . | 1 | 3 | .. | 4 |
| Burma . . . . . . . . . | 142 | 13 | .. | 155 |
| Central Provinces . . . . . . . | 28 | 11 | 26 | 65 |
| Madras . . . . . . . . . | 44 | 11 | .. | 55 |
| North-West Frontier Province . . . . | 6 | .. | .. | 6 |
| Punjab . . . . . . . . . | 6 | 5 | .. | 11 |
| Total of each kind and grand total . | 249 | 52 | 26 | 327 |
| Total for 1931 . | (*a*)271 | 64 | 16 | 351 |

(*a*) Including one Exploring License.

## CLASSIFICATION OF LICENSES AND LEASES.

TABLE 49.—*Prospecting Licenses and Mining Leases granted in Ajmer-Merwara during the year 1932.*

| District. | 1932. No. | Area in Acres. | Mineral. |
|---|---|---|---|
| | PROSPECTING LICENSES. | | |
| Ajmer | 1 | 7·2 | Iron and copper. |
| Do. | 1 | 2·8 | Mica. |
| Do. | 1 | 0·8 | Beryl and felspar. |
| Do. | 1 | 18·4 | Asbestos and greenstone. |
| Beawar | 1 | 3·6 | Asbestos and soapstone. |
| Do. | 1 | 1·6 | Red and yellow ochres. |
| TOTAL | 6 | .. | |
| | MINING LEASES. | | |
| Ajmer | 1 | 4·4 | Kaolin, mica, feslpar, greenstone, muscovite, garnet, and beryl-ore. |
| Do. | 1 | 4·2 | Kaolin. |
| Do. | 1 | .. | Mica. |
| TOTAL | 3 | .. | |

TABLE 50.—*Prospecting Licenses and Mining Lease granted in Assam during the year 1932.*

| District. | 1932. No. | Area in Acres. | Mineral. |
|---|---|---|---|
| | PROSPECTING LICENSES. | | |
| Cachar | 3 | 6,150·4 | Natural petroleum. |
| Lakhimpur | 6 | 15,611·5 | Do. |
| Do. | 1 | 1,190·4 | Coal. |
| Sylhet | 3 | 15,603·2 | Mineral oil. |
| TOTAL | 13 | .. | |
| | MINING LEASE. | | |
| Lakhimpur | 1 | 2,560·0 | Coal. |

TABLE 51.—*Mining Leases granted in Baluchistan during the year 1932.*

| District. | 1932. | | |
|---|---|---|---|
| | No. | Area in Acres. | Mineral. |
| Quetta Pishin . . | 3 | 960 | Coal. |

TABLE 52.—*Prospecting License granted in Bengal during the year 1932.*

| District. | 1932. | | |
|---|---|---|---|
| | No. | Area in Acres. | Mineral. |
| Chittagong . . | 1 | 4,000 | Natural petroleum. |

TABLE 53.—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during the year 1932.*

| District. | 1932. | | |
|---|---|---|---|
| | No. | Area in Acres. | Mineral. |
| | PROSPECTING LICENSES. | | |
| Angul . . . . | 1 | 640·0 | Ochre. |
| Singhbhum . . . | 1 | 408·0 | Chromite. |
| TOTAL . | 2 | .. | |
| | MINING LEASES. | | |
| Singhbhum . . . | 1 | 500·0 | Iron and manganese. |
| Do. . . . | 1 | 356·5 | Chromite. |
| TOTAL . | 2 | .. | |

TABLE 54.—*Prospecting License and Mining Leases granted in the Bombay Presidency during the year 1932.*

| District. | 1932. No. | 1932. Area in Acres. | 1932. Mineral. |
|---|---|---|---|
| | | *Prospecting License.* | |
| Ratnagiri . . . . | 1 | 1,280 | Chromite. |
| | | *Mining Leases.* | |
| Kanara . . . . | 2 | 108 | Manganese-ore. |
| Do. . . . . | 1 | 172 | Chromite. |
| TOTAL . | 3 | .. | |

TABLE 55.—*Prospecting Licenses and Mining Leases granted in Burma during the year 1932.*

| District. | 1932. No. | 1932. Area in Acres. | 1932. Mineral. |
|---|---|---|---|
| | | *Prospecting Licenses.* | |
| Akyab . . . . | 8 | 24,250·4 | Natural petroleum (including natural gas). |
| Amherst . . . | 1 | 640·0 | All minerals except oil. |
| Lower Chindwin . . | 4 | 10,973·0 | Natural petroleum (including natural gas). |
| Magwe . . . . | 5 | 16,916·0 | Do. |
| Mergui . . . . | 33 | 18,291·2 | Tin and allied minerals. |
| Do. . . . . | 17 | 7,655·4 | Tin. |
| Do. . . . . | 3 | 1,081·6 | Tin and wolfram. |
| Do. . . . . | 2 | 768·0 | Tin, wolfram and other allied minerals. |
| Do. . . . . | 1 | 44·8 | All minerals except oil and precious stones. |

TABLE 55.—*Prospecting Licenses and Mining Leases granted in Burma during the year 1932*—contd.

| DISTRICT. | 1932. No. | 1932. Area in Acres. | 1932. Mineral. |
|---|---|---|---|
| PROSPECTING LICENSES—*contd.* | | | |
| Mergui | 3 | 1,817·6 | Tin and all other minerals except oil. |
| Do. | 2 | 659·2 | Gold, tin and allied minerals. |
| Minbu | 1 | 80·0 | Natural petroleum. |
| Myingyan | 1 | 1,280·0 | Natural petroleum (including natural gas). |
| Myitkina | 1 | 512·0 | Mica and other minerals. |
| Northern Shan States | 1 | 640·0 | Gold. |
| Do. | 3 | 3,250·0 | All minerals. |
| Do. | 1 | 38·4 | Iron-ore. |
| Do. | 1 | 320·0 | Lead and silver. |
| Pakokku | 3 | 1,200·6 | Natural petroleum (including natural gas). |
| Prome | 1 | 4,640·0 | Do. |
| Shwebo | 2 | 7,987·2 | Do. |
| Southern Shan States | 4 | 2,534·4 | All minerals except mineral oil. |
| Do. | 2 | 1,280·0 | Wolfram. |
| Tavoy | 22 | 9,164·0 | Tin and wolfram. |
| Do. | 3 | 1,881·6 | Tin and allied minerals. |
| Do. | 4 | 2,835·2 | All minerals except oil. |
| Thaton | 2 | 526·4 | Do. |
| Thayetmyo | 4 | 8,723·2 | Natural petroleum (including natural gas). |
| Upper Chindwin | 2 | 1,267·2 | Coal. |
| Do. | 4 | 13,259·5 | Natural petroleum (including natural gas). |
| Yamethin | 1 | 640·0 | Galena ore and lead. |
| TOTAL | 142 | .. | |
| MINING LEASES. | | | |
| Mergui | 3 | 755·2 | Tin. |
| Do. | 1 | 332·8 | Cassiterite and associated minerals. |
| Do. | 1 | 230·4 | Cassiterite and tin-ore. |
| Tavoy | 3 | 1,760·0 | All minerals except oil. |
| Do. | 2 | 883·2 | Tin and wolfram. |
| Do. | 2 | 2,265·6 | Tin and allied minerals. |
| Thayetmyo | 1 | 2,400·0 | Natural petroleum (including natural gas). |
| TOTAL | 13 | .. | |

TABLE 56.—*Prospecting Licenses and Mining and Quarry Leases granted in the Central Provinces during the year 1932.*

| District. | 1932. No. | 1932. Area in Acres. | 1932. Mineral. |
|---|---|---|---|
| | | **PROSPECTING LICENSES.** | |
| Betul | 1 | 283 | All minerals. |
| Bhandara | 2 | 23 | Manganese-ore. |
| Do. | 1 | 11 | Flooring stone. |
| Bilaspur | 1 | 10,297 | Coal. |
| Chanda | 1 | 225 | Ochre. |
| Chhindwara | 14 | 4,514 | Coal. |
| Jubbulpore | 1 | 51 | Fireclay. |
| Do. | 2 | 8 | Bauxite. |
| Raipur | 1 | 23 | Flagstone. |
| Do. | 1 | 24 | Clay. |
| Yeotmal | 3 | 73 | Limestone. |
| TOTAL | 28 | .. | |
| | | **MINING LEASES.** | |
| Balaghat | 4 | 525 | Manganese. |
| Bhandara | 1 | 9 | Do. |
| Chanda | 1 | 9 | Coal. |
| Chhindwara | 1 | 165 | Do. |
| Jubbulpore | 2 | 2 | Bauxite. |
| Nagpur | 2 | 115 | Manganese-ore. |
| TOTAL | 11 | .. | |
| | | **QUARRY LEASES.** | |
| Bilaspur | 4 | 157 | Limestone. |
| Do. | 5 | 10 | Clay. |
| Chanda | 1 | 5 | White clay. |
| Chhindwara | 1 | 2 | Limestone. |
| Jubbulpore | 2 | 47 | Clay. |
| Do. | 8 | 62 | Limestone. |
| Do. | 1 | 1 | Sand. |
| Nagpur | 2 | 2 | Clay. |
| Do. | 1 | 9 | Building stone, laterite and clay. |
| Raipur | 1 | 18 | Building stones. |
| TOTAL | 26 | .. | |

TABLE 57.—*Prospecting Licenses and Mining Leases granted in the Madras Presidency during the year 1932.*

| District. | 1932. No. | 1932. Area in Acres. | 1932. Mineral. |
|---|---|---|---|
| PROSPECTING LICENSES. | | | |
| Chingleput . . . . | 23 | 902·16 | Barytes. |
| Do. . . . . | 1 | 80·20 | Barytes, iron-ore, and manganese-ore |
| Do. . . . . | 1 | 16·00 | Lead, zinc, and barytes. |
| Do. . . . . | 1 | 6·00 | Kaolin and yellow ochre. |
| Do. . . . . | 1 | 2·00 | China clay. |
| Do. . . . . | 1 | 20·00 | Red oxide of iron. |
| Do. . . . . | 1 | 27·50 | Steatite. |
| Do. . . . . | 1 | 23·68 | Calcite. |
| Do. . . . . | 1 | 2·18 | Lead-ore. |
| Cuddapah . . . . | 5 | 302·46 | Barytes. |
| Do. . . . . | 2 | 347·47 | Asbestos. |
| Do. . . . . | 1 | 325·67 | Barytes and yellow ochre. |
| Do. . . . . | 1 | 46·35 | Galena. |
| Nellore . . . . | 4 | 109·12 | Mica. |
| TOTAL . | 44 | .. | |
| MINING LEASES. | | | |
| Anantapur . . . . | 1 | 49·95 | Barytes. |
| Chingleput . . . . | 1 | 0·95 | White clay. |
| Do. . . . . | 1 | 452·60 | Limestone. |
| Do. . . . . | 1 | 6·95 | Metal and gravel. |
| Do. . . . . | 1 | 64·31 | Steatite. |
| Cuddapah . . . . | 1 | 6·94 | China clay. |
| Do. . . . . | 1 | 8·00 | Yellow ochre. |
| Nellore . . . . | 3 | 9·57 | Mica. |
| Tinnevelly . . . . | 1 | 2·48 | Garnet sand. |
| TOTAL . | 11 | .. | |

TABLE 58.—*Prospecting Licenses granted in the North-West Frontier Province during the year 1932.*

| DISTRICT. | 1932. | | |
|---|---|---|---|
| | No. | Area in Acres. | Mineral. |
| Bannu . . . . . | 3 | 25,011·2 | Natural petroleum (including natural gas). |
| Dera Ismail Khan . . | 1 | 1,321·6 | Do. |
| Do. . . | 2 | 3,145·2 | Mineral oil. |
| TOTAL . | 6 | .. | |

TABLE 59.—*Prospecting Licenses and Mining Leases granted in the Punjab during the year 1932.*

| DISTRICT. | 1932. | | |
|---|---|---|---|
| | No. | Area in Acres. | Mineral. |
| | PROSPECTING LICENSES. | | |
| Attock . . . . . | 1 | 1,053·0 | Natural petroleum. |
| Jhelum . . . . . | 5 | 305·6 | Coal. |
| TOTAL . | 6 | .. | |
| | MINING LEASE. | | |
| Jhelum . . . . . | 5 | 2,360·7 | Coal. |

# GEOLOGICAL NOTES ON TRAVERSES IN TIBET MADE BY SIR HENRY HAYDEN IN 1922. BY A. L. COULSON, M.Sc., D.I.C., F.G.S., *Assistant Superintendent, Geological Survey of India.*

## INTRODUCTION.

**Purpose of paper.**

The purpose of this paper is to give a summary of certain hitherto unpublished notes made by the late Sir Henry Hayden in 1922 in Tibet; and, also, to record the names and localities of certain specimens and minerals collected then by him. These specimens are registered in the collections of the Geological Survey of India under the numbers 32·366 to 32·382.

Certain of the rocks were examined by Mr. C. T. Barber in 1923 and all have been re-examined by the author.

**Delay in publication.**

The delay in the publication of the results of Sir Henry's traverses has been due to a variety of causes. The details in one of Sir Henry's original field notebooks, were transcribed with great care by Sir Edwin Pascoe, who hoped to be able to construct from the notes a geological map of the tracts to the north-west and north of Lhasa. Reference may be made to Sir Edwin's 'General Report for 1925'[1] in which a very brief summary of Sir Henry's work is given. More recently Dr. G. de P. Cotter endeavoured to construct a map. But the details given by Sir Henry in his notes are too incomplete for this result to be obtained.

Sir Henry's second field notebook has only been recently obtained through the courtesy of Mr. A. A. Vlasto, who discovered it among some of Sir Henry's effects. The details given in this book refer to the area to the east and south-east of Lhasa (Traverses 7 and 8 on page 331) and have been transcribed by the author.

[1] *Rec. Geol. Surv. Ind.*, LIX, pp. 18-19, (1927).

Mention may be made here, however, of Plates A and B accompanying Volume V of Sven Hedin's 'Southern Tibet',[1] where Plate B has been constructed from the traverse details given on Plate A.

**Geological maps of Tibet.**

The geological details on Plate B overlap to a slight extent the area traversed by Sir Henry Hayden near Wom-po (31° 24′: 86° 33′), where the rocks are shown by Henning as 'Jura-Neocom: Quartzitische Sandsteine, Phyllite, Jaspis'. Rocks shown by him as 'Spateocan: Liparite, Dacite, Andesite, Basalte' would appear to extend to the area between Nya-pa (31° 0′: 87° 27′) and Shentsa Dzong (30° 57′: 88° 38′).

Sir Henry Hayden's geological map of parts of the Province of Tsang and Ü in Tibet, forming Plate 15[2] of *Memoirs of the Geological Survey of India,* XXXVI, Part 2, shows geological details immediately to the north and west of Lhasa (29° 39′: 91° 8′), the rocks being Crystallines and Cretaceous with large areas of Jurassic rocks further to the north and to the south-east.

Mention may be made here of the brief summary of the geology of the 'Trans-Himalaya' region of Tibet given by E. Trinkler;[3] also of the reference to Sir Henry Hayden's work made by A. M. Heron in the revised edition of Hayden and Burrard's 'Geography and Geology of the Himalaya Mountains and Tibet'.[4]

It may be recalled that a popular account of Sir Henry's expedition to Tibet has been published under the title 'Sport and Travel in the Highlands of Tibet', by Sir Henry Hayden and Cesar Cosson (London, 1927). Apart from brief mention of gold, salt, shales, limestones, sandstones, etc., this book is devoid of geological information. However the regions to the north-west and north of Lhasa, from which the specimens described herein under Traverses 1 to 6 (page 331) were collected, are described in Chapters V to VII (pages 95-190) of this book; the Thak-po region (Traverses 7 and 8) is described in Chapter VIII (pages 191-228). Moreover the map on

**Popular account of Sir Henry's expedition.**

[1] Anders Henning, 'Zur Petrographie und Geologie von Sudwesttibet', Stockholm, (1915).

[2] *See* Plate XLVII of S. G. Burrard and H. H. Hayden's 'Geography and Geology of the Himalaya Mountains and Tibet', Calcutta, (1907-08).

[3] 'Tibet: sein geographisches Bild und seine Stellung im Asiatischen Kontinent', *Mitteil. d. Geogr. Ges. München,* XV, pp. 75-77, (1922).

[4] Pt. IV, 'The Geology of the Himalaya', p. 328, (*in the press*).

the scale of one inch to sixteen miles which accompanies the book, shows most of the places mentioned in this paper.

**Palæontological results of Sir Henry's traverses.**

The palæontological results of Sir Henry's expedition have been published in the form of two papers:—'Some Orbitolinæ from Tibet', by Dr. G. de P. Cotter;[1] and 'Upper Carboniferous Fossils from Tibet', by Dr. F. R. C. Reed.[2] Reference to these papers has been made in the text of this paper.

**Subdivision of traverses for descriptive purposes.**

For descriptive purposes, Sir Henry's journeys described herein may be considered as being composed of the following traverses, the direction and extent of which may be gathered from a study of the sketch map forming Fig. 1:—

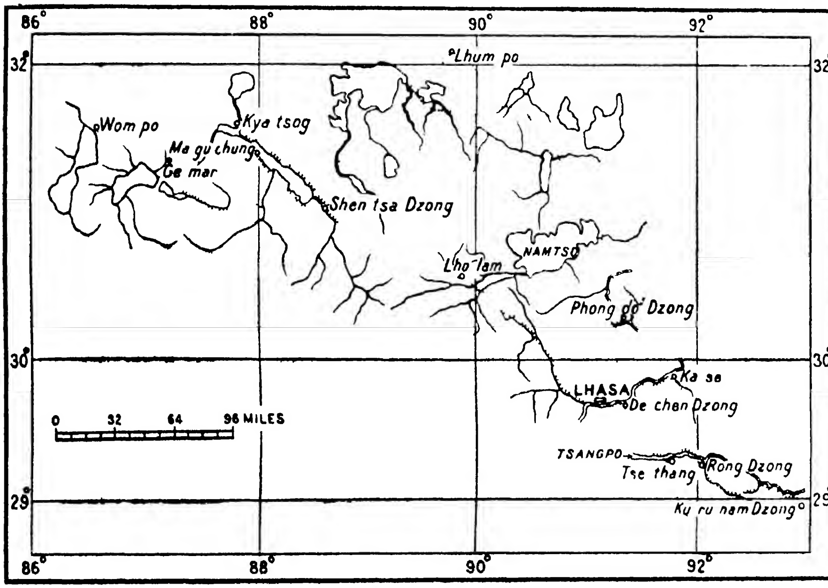



FIG 1.—Sketch map showing the traverses in Tibet (shown by dotted lines) made by Sir Henry Hayden in 1922.

(1) Lhasa (29° 39′: 91° 8′) to Shen-tsa Dzong (30° 57′: 88° 38′).

(2) Shen-tsa Dzong to Wom-po (31° 24′: 86° 33′) on the Tang Ra Tso *viâ* the Lam-lung La (30° 58′: 87° 58′) and Ge-mar (31° 12′: 87° 12′).

[1] *Rec. Geol. Surv. Ind.*, LXI, pp. 350-357, (1929).
[2] *Pal. Ind.*, N. S., Vol, XVI, pp. 1-37, (1930).

(3) Ge-mar to Shen-tsa Dzong *viâ* Ma-gu-chung (31° 19′ : 87° 59′) and the southern shore of the Kya-ring Tso.
(4) Shen-tsa Dzong to Kya-tsog (31° 31′ : 87° 49′) along the northern shore of the Kya-ring Tso.
(5) Shen-tsa Dzong to Lhum-po (32° 6′ : 89° 41′) between the Tso-Zi-ling and the Pang-gok Tso.
(6) Lhum-po to Lhasa *viâ* the eastern end of the Nam Tso.
(7) Lhasa to Ku-ru-nam Dzong (28° 57′ : 92° 55′) *viâ* De-chen Dzong (29° 40′ : 91° 25′), the Te-khar La (29° 32′ : 91° 58′) and Rong Dzong (29° 14′ : 92° 5′ ).
(8) Ku-ru-nam Dzong to De-chen Dzong *via* Tse-thang (29° 15′: 91° 46′).

Traverses Nos. 1 to 6 are to the north-west and north of Lhasa ; whilst Nos. 7 and 8 are to the east and south-east of Lhasa.

## I.—LHASA TO SHEN-TSA DZONG.

Sir Henry mentions the occurrence of shales and rhyolitic rocks between Lhasa and Ma-ra (29° 50′ : 90° 40′) in the Talung valley, the lavas containing inclusions of shales. A specimen (32·366) collected by him is unfortunately missing from the collections ; it was not described by Mr. Barber.

The rhyolitic rocks continue to within half a mile of Se-shing where there occurs a belt of folded calcareous rocks, one to one and a half miles wide, containing intrusive rocks. A specimen (32·367, 22228) from half a mile south-east of Se-shing effervesces readily with cold dilute hydrochloric acid. It is a ferruginous oolitic limestone.

Proceeding north-west to Hyang-pa-chen (which is the same or very near Zam-sar ; 30° 6′ : 90° 33′), rhyolites soon cover a quartzite series which overlies the shales and limestones, and fill the whole valley to half way between De-chen and Hyang-pa-chen, where they are found in contact with granite. The granite continues to the latter place.

The track from Hyang-pa-chen to Pha-ngo-chi-li (30° 14′ : 90° 25′), about sixteen miles distance, passes for some way in a narrow valley in granite or gneissose granite. This rock continues from the latter place to Lug Lam (30° 14′ : 90° 18′) at the foot of the Gu-ring glacier, and all the surrounding peaks appear to be of this rock. Sir Henry observed no coarse rock or pegmatite, but noticed one pebble of 'schorl-granite'.

Between Lug Lam and Tho-gar-gyab-lung (30° 24′: 90° 4′), a distance of 20-22 miles, the rocks are granite till north of G La, where a band of slate, very much altered, is met. This is followed by more granite and then by quartzite, shale and a conglomerate with few pebbles.

The track from here to Dong-ro-chang-ma, which is about four miles from Lho-lam (30° 30′: 89° 51′) passes over pebbly grits and conglomerates that resemble no other Indian rocks that Sir Henry had met previously. The same rocks continue to Lho-lam.[1] A specimen (32·368) collected by Sir Henry from Lho-lam, which unfortunately is missing, was described by him as a '?breccia in igneous series'. About half a mile west of Lho-lam, the pebbly grits, shales and sandstones form an anticline striking east to west along the valley. They are intruded by a dark basic rock which has baked the shales into hard slate. Sir Henry noted granite blocks but did not observe this rock *in situ*. The shales continue to Bog-kyang-nyin (30° 33′: 89° 42′).

The specimens collected from Shota,[2] about ten miles north-west of Lho-lam have been registered by Sir Henry under two numbers. Those under the first (32·369, 22229) are best described as porphyrites or andesites but two are distinctly more basic than the other specimens, and consist mainly of phenocrysts of felspar and masses of epidote set in a fine-grained, dark, cryptocrystalline to glassy groundmass. The more acidic specimens (22249) contain abundant quartz phenocrysts and predominant orthoclase. The specimens registered under the other number (32·370, 22230) are likewise porphyrites of varying acidity. The thin section shows resorbed quartz in addition to abundant perthite, some orthoclase and plagioclase, and, also, calcite, abundant chloritic material, possibly as pseudormorphs after biotite, and magnetite.

The same pebbly series apparently occurs in the 14 miles between Bog-kyang-nyin and Hle-ngombo (close to Genchung; 30° 37′: 89° 29′) being chiefly red sandstones containing very small clay balls on certain bedding planes. The series appeared to Sir Henry to be a fresh-water one and curiously like the Upper Gondwanas, but he presumed it to be Lower Tertiary in age. The pebble beds

[1] Sir Henry collected Upper Carboniferous fossils from this locality. *See* F. R. C. Reed, *op. cit.*, pp. 1, 3-4.

[2] This is not the Sho-tra-sa-tsi mentioned on the next page.

and the usual apparently basic rocks are represented in all the debris on either side of the valley.

The same pebbly series continues to Sho-tra-sa-tsi (30° 40′: 89° 20′), red sandstones forming the hills along the northern side of the route, and for the eight miles from this place to I-ri (? Ta-me-sa-tsi; 30° 43′: 89° 10′) where it is replaced by igneous rocks. A specimen from here (32·371, 22231) is a banded rhyolite, containing occasional phenocrysts of quartz and also bands of very fine-grained mosaics of quartz.

The route from I-ri to A-chen-tsongo (30° 49′: 88° 49′) passes through sandstones and then a spotted volcanic rock, described by Sir Henry as an andesite, slaty rocks and flaggy sandstones. He considered them to belong to the same pebbly series. He noted a dark blue-grey limestone, with calcite streaks, to cover the hills far away to the north, and also to the south, appearing to overlie the pebbly series.

Between A-chen-tsongo and Shen-tsa Dzong (30° 57′: 88° 38′), on the southern side of the valley, there is a snowy *massif* composed apparently of sedimentary rocks. On the northern side are hills of dark grey limestone with many calcite veins and sections of gastropods.[1]

Sir Henry states that the rocks on the northern side of the valley near Shen-tsa Dzong are nearly all limestone much altered and full of calcite veins. This is presumably the same Upper Carboniferous limestone referred to previously. The rocks on the southern side are mostly basic intrusives with some quartzite, slate and pebble beds. The sequence is evidently the pebble beds, sandstones, etc., with much basic igneous material at their base, and then above this limestone, very thick, with some shaly beds intercalated. It may be that Sir Henry's view that the limestone runs up at least to the Triassic is correct.

Two kinds of specimens have been registered by Sir Henry under the number 32·382 as being collected from two miles south of Shen-tsa Dzong. One type (22233) was described by Mr. Barber as being an amygdaloidal basalt, being a dark brown rock, fine-grained, with masses of amygdales of calcite. The slide shows abundant serpentine probably after olivine and augite, and, also,

[1] *See* F. R. C. Reed, *op. cit.*, p. 1, locality 2. Many Upper Carboniferous fossils were collected from the foot of the limestone ridge, five miles east of Shen-tsa Dzong.

occasionally in amygdales. A few small crystals of augite remain. The second type (22232) is very much more acidic and is toscanitic in nature.

## II.—SHEN-TSA DZONG TO WOM-PO.

**Resemblance to the Panjal trap series.**

The rocks between Shen-tsa Dzong and Nan-dzum (30° 57′: 88° 23′), which is some 14 miles to the west, are chiefly lavas and ashes which are very similar in appearance to the Panjal trap series. The hills to the south must contain granite as Sir Henry found numerous granite boulders in the valleys leading down to the Nakt-sang valley and the Kya-ring Tso.

**Similarity to Gondwanas.**

These volcanic rocks persist almost to Mi-bar (31° 4′: 87° 16′). Between Nan-dzum and the Pa-ro Tsangpo river (30° 56′: 88° 4′), sandstones occur here and there in small quantity. Between the river and Chu-tra-ri (30° 58′: 87° 53′), near the latter place, Sir Henry noted slaty beds on the col, and lower down thin-bedded flaggy sandstones, not much altered and resembling the Gondwanas in appearance. Granite, quartzite and slate boulders were observed on the way to Gon-khyok (30° 55′: 87° 39′).

**Pleistocene lake deposits.**

At Nya-pa (31° 0′: 87° 27′) are some Pleistocene lake deposits and in the hills to the north, beds of slate or thin-bedded sandstones dipping north-west and striking N. E.–S. W.

**Specimens from Mi-bar.**

Two specimens from Mi-bar are very interesting. The first (32·373, 22235) was described by Sir Henry as being from a small patch of ?Tertiary shales and indurated white fire-clays in a bay in a small valley north of the Ma-khar Tso. It appears to be an indurated shale. The second (32·372, 22234) is a quartz-porphyry which, according to Sir Henry, intrudes or overlies thin flaggy red sandstones. Mr. Barber states that the slide shows numerous phenocrysts of quartz, many of which show corrosion, a few comparatively fresh crystals of both orthoclase and plagioclase, and small flakes of biotite in various stages of decomposition, together with chlorite, serpentine (probably after hornblende) and a matrix of alkali felspar with little mica.

With regard to the ?Tertiary shales, these beds contain near the top a band of carbonaceous shale that has locally been mistaken for coal. A pit about 30 feet deep has been sunk prior to Sir Henry's arrival[1] but the carbonaceous shale is only near the surface and the rock is the indurated white shale described previously. There is no sign of coal and the beds are almost horizontal, being but slightly disturbed.

**Carbonaceous shale.**

The rocks are mostly quartz-porphyries between Mi-bar and Ge-mar (31° 12′: 87° 12′). No rocks occur *in situ* between this latter place and Ngo-gen[2] (31° 13′: 86° 51′) but between here and Chu-gyur (31° 15′: 86° 41′), igneous rocks predominate, Sir Henry noting but one mall patch of limestone and another of quartzite. He collected a specimen (32·374, 22236) of pitchstone from the hills four miles north-east of Chu-gyur. This has a slight tendency to perlitic structure, but not well developed. Another specimen (32·374A, 22250) is a largely altered porphyrite, bluish green celad-onite and calcite being among the products of decomposition.

**Predominance of acidic rocks.**

The rocks on the first col. between Chu-gyur and Wom-po (37° 24′: 86° 33′) are igneous. Limestone, however, occurs in patches in the hills to the north-west and also in the main valley below and on the way up to the second pass (Ne-thung La; 31° 17′: 86° 37′). The limestone contains Upper Carboniferous fossils.[3] Half-way between the two passes, there is a ridge of volcanic ash with a coarse boulder bed containing rounded blocks of the usual lime-stone; the boulder bed is vertical. Three chips of the intrusive igneous rocks (32·375) collected by Sir Henry between La-u La (31° 15′: 86° 39′) and Ne-thung La, vary largely in grain. One (22237) is a rather acidic diorite of porphyritic texture; a second (22238) is a quartz-felspar-porphyry; whilst the third (22239) is possibly a dacite.

The second pass (Ne-thung La) is all igneous from about half way up, but the ridge to the north is limestone. This limestone is again seen near the western foot of the pass and, also, about seven miles south-east of Wom-po (31° 24′: 86° 33′), where the path crosses

**Rocks similar to the Middle Halmantas.**

[1] 4th June, 1922.

[2] Sir Henry collected specimens of Upper Carboniferous fossils from rocks not *in situ*. *See* localities 4 and 6 in F. R. C. Reed, *op. cit.*

[3] *See* F. R. C. Reed, *op. cit.*, locality 5.

a ridge of this rock and descends on to shale and quartzite. This is the beginning of a highly metamorphosed series which extends to Wom-po and is very similar to the Middle Haimantas. There are, however, occasional bands of highly altered calc-slate or calc-schist. Two miles from Wom-po, a bed, 20 to 30 feet thick, of white quartz crosses the hillside, dipping towards the lake. It contains no minerals.

**Pleistocene lake terraces.**

The lake (Tang Rao Tso) is surrounded by a wonderful series of 20 or more terraces, the highest being nearly 500 feet above the level at the time of Sir Henry's visit.[1] They are comparable with the Karewas. The old lake deposits often dip at 25° to 30° towards the lake.

**Alluvial gold workings at Wom-po.**

Sir Henry visited the supposed alluvial gold workings at Wom-po, which however, were not being worked,[2] nor was any worker expected to arrive till late in June.

## III.—GE-MAR TO SHEN-TSA DZONG *VIA* MA-GU-CHUNG.

The route from Ge-mar (31° 12′: 87° 12′) to Lang-chen-ge-guk (31° 13′: 87° 20′) is over volcanic rocks, among which are agate fragments. Soon after leaving here, granite is found and then an igneous and sedimentary series, with isolated patches of limestone. Just before the descent into the valley of the Kya-ring Tso, near Ma-gu-chung (31° 19′: 87° 59′), the hills on the north and west contain a belt of limestone (presumably Upper Carboniferous) with the usual fossil corals. This is soon replaced by the igneous series (? the one similar to the Panjal trap series) which appears to underlie the limestone. A specimen (32·376, 22240) from here is of the nature of a felspar-porphyrite. Similar rocks form the hills along the southern side of the Kya-ring Tso. The hill in the middle of the plain and west of Di-na (31° 8′: 88° 10′) has well-bedded rocks which Sir Henry considered to be apparently basaltic or other lavas. A specimen (32·377, 22241), however, collected from a hill north-east of Di-na between there and the lake is more acidic, being a trachyte to a trachy-andesite in nature. The rocks between

[1] 8th June, 1922.
[2] On the 9th June, 1922. *See* also 'Sport and Travel in the Highlands of Tibet', p. 145.

Di-na and Shen-tsa Dzong are chiefly igneous with some slate and quartzite in the moraines.

## IV.—SHEN-TSA DZONG TO KYA-TSOG.

The northern shore of the Kya-ring Tso is formed of Upper Carboniferous limestone in continuation of the hills north of Shen-tsa Dzong. Just before Pe-chen (31° 8′ : 88° 27′), a small promontory runs out into the lake, being composed of quartzite, overlain by slate or slaty shale. These are overlain by much altered limestone with many calcite veins. Sir Henry noted many bryozoa in blocks of limestone forming the fan at Pe-chen.[1] The same features occur past A-rock (31° 15′ : 88° 15′) and Chu-sum-di (31° 24′ : 88° 1′), limestones overlying quartzites and shales. At the latter place, there is an anticline running along the lake about one mile inland. Sir Henry considered the lake (Kya-ring Tso) possibly to be along the line of a fault and mentions that breccias are very common along its edge.

Limestone forms most of the route from Chu-sum-di to Kya-tsog (31° 31′ : 87° 49′). A small ridge between the limestone masses at Kya-tsong, consists of beds of clay sandstones and nodular limestone, the latter being full of oysters, and forams.[2] Many septarian nodules occur in the lower part of the series. Occasional small patches of worthless lignite were seen. Strike faulting is conspicuous here.

Sir Henry mentions that serpentine is intrusive in the bed under the shale and sandstone series.[3]

## V.—SHEN-TSA DZONG TO LHUM-PO.

Between Shen-tsa Dzong and Nunjutala, a distance of some eight miles, limestone overlies slate and quartzite. At Yun-druk (31° 15′ : 88° 43′), there is a good section of a buff sandstone similar to Gondwana rocks in appearance, capped by a pebbly grit and overlain by limestone.[4] Limestone continues most of the way to Lug-thang (31° 22′ : 88° 51′) and from there to Se-jong (31° 28′ :

[1] *See* locality 8, F. R. C. Reed, *op. cit.*

[2] *See* G. de P. Cotter, *op. cit.*, for the age of the *Orbitolina.*

[3] Sir Henry marched back to Shen-tsa Dzong on the eastern side of the hill Te-nak (19,420 feet) *via* Kam-sang La (31° 27′ : 87° 57′), arriving there on the 25th June, 1922.

[4] *See* locality 9, F. R. C. Reed, *op. cit.*

89° 0′) where, however, granite occurs. This is probably the locality Se-tsok, described as being some 20 miles south of the Tso-Zi-ling,[1] from where Sir Henry collected a specimen of adamellite (32·378, 22242). This is described by Mr. Barber as a coarsely crystalline rock containing abundant quartz, orthoclase (both fresh and altered), a little microcline, and plagioclase (fresh, some with zoning and some sauss-uritised). There is also biotite, a little hornblende, some chlorite and a little magnetite.

The adamellite continues between Se-jong and De-to (31° 34′: 89° 7′) till the plain of the Tso-Zi-ling, when limestone crops out, and then adamellite once more. At the latter place, there is a great ridge of red quartzite which runs E.–W. to the limestone hills. This is probably the sandstone below the Upper Carboniferous limestone.

The route from De-to to Tong-chu (31° 50′: 89° 20′) runs across a huge plain with innumerable old lake beaches. At Tong-chu,

**Pleistocene lake beaches at Tong-chu.**

a valley about 20 feet deep cuts through the Pleistocene lake deposits which can be seen to be clays and sandy clays or argillaceous sandstones, horizontal at the camp, but elsewhere with a marked dip.

In the sandy beds are small patches of lignitic material, the thickest of which is only about three-quarters of an inch and only

**Lignite at Tong-chu.**

a few inches long. It is a supposed coalfield, but it is quite valueless.

From Tong-chu, Sir Henry marched to A-bi-tang-kha (31° 58′: 89° 34′) eastwards across the great plain south of the Tsa-khye

**Salt.**

Tsangpo river and north of the Pang-gok Tso, which lake is covered with salt.[2] The country through which he passed is a mass of old lake basins, then mostly dry, but containing a small quantity of highly saline water. Springs of fresh water were seen on the shores. There are hills of limestone (? Upper Carboniferous) east of the Pang-gok Tso.

At Lhum-po or Limbu (32° 6′: 89° 41′) the farthest north of Sir Henry's traverses, there is a small ridge about 2,888 feet high

[1] 'Sport and Travel in Tibet', p. 164.

[2] In 'Sport and Travel in Tibet', Sir Henry mentions (p. 167) that 'Pang-gok is a borax lake, and a small industry is carried on there during the summer. The borax is found as an efflorescence on the soil at the shores of the lake; it is scraped up and boiled in cauldrons, the impurities are separated and the borax is crystallised out by evaporation. Boiling is a tedious process in a country in which the only fuel is yak-dung.'

and four or five miles long in the middle of a great plain. The hill consists of a series of paper shales and calcareous shales and clayey beds, dipping in all directions and forming a very fine dome. A vein of asphalt (L 896), about eight inches thick, is exposed in the lowest beds of the dome.[1] The beds are horizontal in the centre for perhaps half a mile each way and then the dip increases gradually to 30° or so. There is no trace of fossils and Sir Henry could only guess the age of the rocks as Tertiary.

## VI.—LHUM-PO TO LHASA.

Between Lhum-po and Trak-chu (31° 51′: 90° 2′), which lies to the south-east, there are hillocks to the north-east and north which are also possibly Tertiary in age, but there are no rock exposures.

**Tertiaries.**

On the eastern side of the plain, the hills contain beds of red sandstone and pebble beds which are probably the same as those noted not far from Shen-tsa Dzong. The strike is approximately south-west to north-east (nearly W.-E. at Trak-chu). Below these are beds of lava with interbedded red sandstone. The volcanic series appears to underlie and to be interbedded with sandstones and conglomerates, but this is not certain. A specimen of the igneous rocks, collected by Sir Henry is (32·379, 22243) described by Mr. Barber as a porphyry, containing phenocrysts of red and white felspars in a reddish brown matrix; orthoclase predominates over plagioclase. The matrix consists of dispersed felspar, some mica, a few small iron-stained areas and many small crystals of felspar.

The route followed by Sir Henry between Trak-chu and Zi-ri-mar (31° 45′: 90° 11′) passes over sandstones and conglomerates and the acidic igneous series, except for one mile in the middle where quartzite occurs. Soft clays in the hillside at Zi-ri-mar dip at about 70°-80° into the hill and contain thin carbonaceous beds one to four inches thick. Some of these pass into lignite but the bands are not continuous and thin out to mere streaks.

Across the plain to Ziri Gompa (31° 45′: 90° 17′) where Sir Henry met the first house since leaving Se-jong (31° 28′: 89° 0′),

[1] *Rec. Geol. Surv. Ind.*, LIX, p. 19, (1927).

**Granite.**

there is a granite ridge striking N. W.–S. E. The granite is probably intrusive into the sandstone and conglomerate series.

Between Ziri Gompa and Nag-rab-chu-kang (31° 43′: 90° 23′), there is first granite and then limestone and slates, quartzites, etc., with no signs of fossils. From there to Be-la-chen (31° 31′ : 90° 38′), which is different from the Lachen (31° 40′: 90° 35′) which is to the west of the Da-rum Tso, the limestones and grits are intruded by granite, diabase and serpentine, which have metamorphosed them. Slate occurs at Be-la-chen.

The igneous and sedimentary rocks continue to Me-za-gyab-lung (31° 20′: 90° 43′), which is to the east of the small lake Pam Tso.

**Porphyrite.**

Specimens (32·380, 22244) from here vary in texture from a porphyrite almost to a grano-diorite. Plagioclase is dominant over orthoclase and the rock also shows quartz, biotite, chlorite, magnetite and a little hornblende. This rock continues about Khung-ma (31° 4′: 90° 57′) and on to Thak (30° 54′: 91° 7′), with some metamorphosed sedimentary inliers. No rocks occur *in situ* along the plain east of the Nam Tso lake, except for a small ridge which runs down evenly to the lake from the east, which is composed of hard whitish quartzite.

Sir Henry's route continued by the Lar-gen La (30° 39′: 91° 5′) to the Dam Chu river (30° 33: 91° 13′). The rocks are limestones and grits of the northern side of the pass.

**Staurolite-and chiastolite-schists.**

At the top of the pass are slaty limestone and slates which pass into phyllites with staurolite- and chiastolite-schists. Similar rocks continue down to the valley of the Dam Chu.

From the Dam Chu, Sir Henry passed first over a plain and then up a long valley to the La-nye La (30° 28′: 91° 17′). The rocks

**Sandstone 'dyke'.**

at first are quartzite and slate, but about three-quarters up the valley, the boulders are pebbly grits and sandstones. About the same place, great masses of a red conglomerate, perhaps 1,000 feet or more thick, are dipping at about 30° to the south. In these, a wonderful 'dyke' of sandstone, perhaps ten feet thick, runs across the bedding through a vertical height of 400 to 500 feet. Sir Henry wondered if the 'dyke' were the toe of a spur against which the conglomerates were deposited. He thought that the conglomerates, which contain pebbles of quartzite and grey limestone with many calcite veins, are Tertiary in age.

The La-nye La itself is over conglomerate beds dipping at a gentle angle to the south or south-west, and later becoming horizontal. At his La-nye camp (? Dong-chung), the dip is steep.

**Upper Carboniferous limestone.**

Sir Henry marched to Phong-do Dzong (30° 15′ : 91° 22′), noting that limestone extends south-east along the hills above the small pass below La-nye. It is full of crinoids and brachiopods[1] and was thought by him to be similar to the limestone at Nakt-sang. Conglomerate overlies it.

The limestone is replaced further down the valley by slates and quartzites, pebbly quartzites, and limestone of the 'grit and sandstone' series, which are intruded by porphyries.

Of the four specimens of igneous rocks (32·381, 381A, 381B, and 381C ; 22245-22248) collected by Sir Henry between Phong-do Dzong and Ta-lung Gompa (30° 11′ : 91° 15′), two are porphyries and two trachy-andesites. The first two contain phenocrysts of quartz, plagioclase, orthoclase and biotite, with a little chlorite, magnetite and pale green augite in a microcrystalline mass of felspar, little mica and quartz. The third is a fine-grained rock with a tendency to conchoidal fracture ; it contains plagioclase, orthoclase, a few pseudomorphs of chlorite after biotite, and magnetite. The last shows a trachytic structure and the phynocrysts are well-orientated in a definite direction.

The prevalence of granite boulders in the river here at Phong-do Dzong indicates that this rock is not far distant.

The acidic igneous series continue up the route to the Chak La, but Sir Henry noted granite one mile below the pass on the Ta-lung side. On the descent on the northern side of the Chak La, dark grey limestone, dipping north, is underlain by a folded group of red shaly sandstone and thin limestone bands. The folding is well seen at Lhun-dub Dzong (29° 57′ : 91° 17′). The limestone here contains *Orbitolina*.[2]

**Sandstone resembling limestone.**

The rocks on either side of the valley along the route to Lang-dong Dzong (29° 53′ : 91° 12′) are red shales and sandstones, the latter being in beds five to 30 feet thick and separated by thin shales. The sandstone is covered with grey lichen and was mistaken at first for limestone, which it resembles in a most remarkable manner

[1] *See* locality 10, F. R. C. Reed, *op. cit.*

[2] *See* Cotter, *op. cit.*, for the age of the fossils.

This red series occurs below the Lhun-dub Dzong limestones. It is much folded but must be not less than 1,000 feet thick.

**Return to Lhasa.**

No notes are available of Sir Henry's journey for the short distance between Lang-dong Dzong and Lhasa (29° 39′: 91° 8′). Reference may be made, however, to his map forming Plate 15 of *Memoirs of the Geological Survey of India*, Volume XXXVI, Part 2.

## VII.—LHASA TO KU-RU-NAM DZONG *VIA* DE-CHEN DZONG, THE TE-KHAR LA AND RONG DZONG.

**Granite.**

Granite occurs between Lhasa and Dechen Dzong (29° 40′: 91° 25′) and has been mapped as Crystallines on Sir Henry's geological map of the Province of Tsang and Ü.[1] Between De-chen Dzong and Ti-khang (29° 46′: 91° 39′) granite is found first and then metamorphic and acid igneous rocks, with limestone for some distance in the middle.

From Ti-khang, Sir Henry marched up the valley to the south-east, noticing limestone and a somewhat fine-grained quartzite for most of the way, and then slate and acid igneous rocks. Acid igneous rocks junction with the base of masses of grey limestone about 1½ miles from the head of the valley (about eight miles from Ti-khang).

**Predominance of granite.**

Slate, limestone and quartzite, with the last most abundant, occur between Ti-khang and Metu Kongkar (29° 51′: 91° 46′).

These same rocks occur in the main valley to Ka-kya Gompa La (29° 43′: 91° 56′), but in the side valley, they are replaced by acid igneous rocks, mostly granitic. Between here and Ding-na (29° 32′: 91° 56′), metamorphics and granite occur. Granite forms the pass and, on the southern side, slate, limestone and quartzite occur for some miles, and then more granite and metamorphic rocks. Limestone crops out at Ding-na.

After leaving Ding-na, Sir Henry marched to two miles below Won Dzong, passing over granite and crystallines. This Won Dzong is not shown on the map accompanying Sir Henry's and Cosson's book, but it cannot be far from Sim-khar-shi (29° 22′: 91° 51′).

[1] *Mem. Geol. Surv. Ind.*, XXXVI, Pt. 2, Pl. 15. De-chen Dzong is the most easterly spot shown coloured on that map.

Sir Henry then travelled to Chos-to (not shown on the map) through the valley of the Tsangpo river, noting igneous rocks and then slates with quartz veins, and quartzites. From there to Lhagyiri Dzong (29° 3′ : 92° 15′), and to Lhap-so Dzong (29° 4′ : 92° 34′), over the Pho-trang La, the same slates with quartz veins continue, with some limestone in the slate.

**Alluvial gold workings.**

Sir Henry mentions old workings for gold in his book, noting that he visited Lhap-so 'to spend a few days here to investigate some old workings for gold high up on the ridge above us to the south'.[1]

He then proceeded to the river above Shi-gong, which is not shown on his map but which is probably not far Khya-tsa Dzong (29° 0′ : 92° 35′).

**Valley of Tsangpo river.**

Sir Henry then followed the route shown in Fig. 1, proceeding along the valley of the Tsangpo river to near Hu-li (29° 1′ : 92° 54′), there being slate, shale, and occasional sandstones and quartzites on the southern side, but granite on the northern side near Drum-pa (29° 6′ : 92° 37′).

## VIII.—KU-RU-NAM DZONG TO DE-CHEN DZONG *VIA* TSE-THANG.

**Fragments of mica ; garnets.**

Sir Henry marched over the Kam-pa La to Chum-do Khyang (92° 2′ : 28° 52′) noting a deserted place which is probably the 'Lhagong' which he mentions in his book (page 217) as having once been a prosperous gold-mining centre. He followed the route over the Ya-to-tra La to Ra-mo-nang over granite which forms the ranges west of the Chum-do plain. The soil is full of glittering fragments of mica, which may have given rise to the idea that there are diamonds in quantity on the Ya-to-tra La. The central part of the range, over the pass, is composed of garnetiferous micaceous gneiss, and then, proceeding west, of granite again. Lower down, the rocks on either side of the valley are garnetiferous schists. They are full of lenticles and small gash veins of quartz.

**Return to Lhasa.**

Below the peak Ya-la Shem-bu, granite and acidic rocks (?hypabyssal), considered by Henry to be the equivalents of those he met in the valley of the Kyi Chu river were met. These acidic rocks continue between the Tsangpo and Kyi Chu rivers to Lhasa, with some limestone and slate near De-chen Dzong.

[1] 'Sport and Travel in Tibet', p. 211.

# The Origin of the Streaky Gneisses of the Nagpur District. By W. D. West, M.A. (Cantab.), *Assistant Superintendent, Geological Survey of India.* (With Plates 12-16.)

## THE PROBLEM.

The metamorphosed sedimentary rocks which are prominently developed in the Nagpur and Chhindwara districts of the Central Provinces have been named by Dr. L. L. Fermor the Sausar series.[1] Associated with these rocks there is always a large development of rather coarse-grained biotite-gneisses which, from their general appearance, have been termed 'streaky gneisses' by Dr. Fermor. These rocks often occupy as large an area as the Sausar series itself; but they are to be distinguished from those schists and gneisses of sedimentary origin which form part of the Sausar series by the fact that, unlike the latter, they are not confined to any particular horizon, but may occur adjacent to any stage of the Sausar series.

A marked feature of these rocks is that they are always full of intrusions of coarse pegmatite, which must sometimes make up as much as half of the whole outcrop of gneiss. These pegmatites occur also in the Sausar series, but on nothing like the same scale.

The question of the origin of these streaky gneisses has never been discussed; but the tacit assumption seems to have been made that they are igneous in origin, without considering the matter further. Certainly the general effect of abundant pegmatites associated with coarsely banded acid gneisses is suggestive of the whole being of igneous origin.

For a number of years now the writer has been making a detailed geological survey of the one-inch sheet 55 O/6, which is situated on the borders of the Nagpur and Seoni districts, some fifteen miles north of Ramtek. The main road from Nagpur to Seoni, the 'Great North Road', crosses this sheet from south to north. In the centre of the sheet is the village of Deolapar, where there is a good Dak bungalow, at 40 miles from Nagpur and 38 miles from Seoni. The area is thus easily accessible.

[1] *Rec. Geol. Sur. Ind.*, LIX, pp. 77-79,

During the course of this work several exposures have been encountered which have thrown light on the origin of these streaky gneisses, and have in fact suggested that they are composite gneisses, formed by the intimate penetration of one rock by another. And though it is not claimed that all those rocks which have been grouped together under the general term of streaky gneiss have been formed in the same way, yet the detailed study of the rocks in one place, where the process of formation is clearly seen, may throw light on the origin of similar rocks elsewhere where the earlier stages of formation are not so well displayed.

The typical streaky gneisses which are the subject of this paper are coarse-grained muscovite-biotite gneisses, with the muscovite much less abundant than the biotite, and frequently quite absent. They are always well banded, in a streaky way, the bands being of two kinds. The finer and darker are a medium-grained biotite-granulite, while the coarser and lighter are an acid, aplite-like rock free from biotite, and consisting almost entirely of quartz and felspar. These aplite bands may constitute considerably more than half the rock, or they may be very scarce, there being every gradation in between. Sometimes the banding is fairly regular; at other times there may be rapid variation from place to place in the proportions of the different bands. But nearly always there is a well-marked parallelism, which gives the rock a typical gneissose appearance.

On the one-inch sheet 55 O/6 the streaky gneisses are well displayed in the Telia *nala*, the stream which forms the boundary between the Seoni and Nagpur districts, and especially in that part of it west of the main road. They are again well developed in the belt of gneisses which extends right across the map, crossing the main road between milestones 42 and 45. They are absent, however, from the belt of sediments which crosses the main road between miles 37 and 41½; but they come on again south of this belt to form the southern half of the sheet.

## POSSIBLE MODES OF ORIGIN.

Such banded gneisses as we are dealing with here might have originated in several ways:—(1) The banding may have been due to some special mode of crystallisation of an originally homogeneous magma. (2) The bands might have been formed by the movement of a mixed liquid or semi-liquid rock under pressure, whereby the

mixture became drawn out into bands of variable composition. (3) The rock may be composite in origin, formed of a mixture of igneous and sedimentary material, or of two varieties of igneous material.

The first explanation has frequently been put forward to account for the formation of banded gneisses, but no adequate explanation has ever been given of the mode of crystallisation by which such banding could have been produced. Vague reference is made to 'rhythmical precipitation', or to 'segregation'; but until it has been shown exactly how melanocratic and leucocratic bands, or biotite-rich and biotite-free bands, came to be precipitated alternately, the suggestion need not be considered seriously.

In this area there is no doubt that many of the streaky gneisses have a composite nature, as referred to under (3) above. Whether they have also been formed in the manner described under (2) is more open to doubt, though it is possible that some of the intrusion of the aplite took place prior to or at the time of the intrusion of the rest of the rock, assuming in this case the rest to be igneous. An example of this nature will be given below in section 8.

## THE STREAKY GNEISSES IN THE DHORIA *NALA*.

It has already been stated that the proportions of the different bands in these streaky gneisses varies greatly from place to place. It is only rarely, however, that the white aplite bands form much less than 50 per cent. of the whole rock. These, however, are just the very ones which provide evidence of the origin of the rocks, and it is to a consideration of them that we may now turn.

An excellent exposure of these streaky gneisses in the less advanced stages of formation is provided by the Dhoria *nala*, less than half a mile south of Nawegaon (21° 36′ : 79° 26′ 30″). Examination of those rocks in which the aplite bands are rather scarce shows at once that these bands are intrusive with respect to the rest of the rock. Occasionally they cut right across the foliation of the rock, while sometimes they can be seen to bifurcate and give off side branches which run along the foliation. Where these acid bands become more abundant they tend also to become thinner, and discordant relations are less commonly observed. In the extreme stage the aplite bands are so abundant that the rock as a whole appears homogeneous; and were it not for the fact that the

earlier stages can be seen close by, there would be no reason to suppose the rock to be composite in origin A set of three photographs has been taken of the rocks in this exposure, and they illustrate well the case in which the intrusive nature of the acid bands is fairly clear, with permeation less advanced in Plate 12, fig. 1, and more complete in Plate 13, fig. 2. The rock which forms the darker lenticles in these photographs is one of those rocks which are difficult to name. There is not sufficient mica to give the rock a pronounced schistosity, nor is there any well-marked banding to justify the term gneiss. On the other hand there is rather more biotite than one expects to find in a typical granulite. Nevertheless the latter term is the one which I have found it most convenient to use. The light acid bands need no description. They are composed of quartz and felspar, with or without a little muscovite.

The importance of this exposure lies in the fact that the greater part of the rock seen is not the type reproduced in these photographs, but the more common streaky gneisses in which the acid bands are very abundant and the banding as a whole less clearly defined. Outcrops of these rocks are difficult to photograph satisfactorily so as to bring out the banding, and therefore a photograph of the hand-specimen is reproduced on Plate 13, fig. 1. The intrusive nature of the acid bands shown in the other photographs is clear and needs no argument. And it is, therefore, very probable that the more homogeneous streaky gneisses near by, differing only in having a larger proportion of acid material and in showing no discordances between one band and another, have had a similar origin. But before giving the complete argument for these conclusions, a few other exposures will be described.

## STREAKY GNEISSES IN THE TUNDIA *NALA*.

A good exposure of these gneisses is seen in the Tundia *nala*, rather more than a mile E. N. E. of Belda (21° 35′ : 79° 22′). South-east of where the Belda-Pindkapar road crosses the river there occur several small islands, which are shown on the one-inch map. These are formed of the gneisses in question, and the outcrops extend for about half a mile upstream above the road crossing. Two varieties of streaky gneiss are found here, and those that make up the eastern half of the outcrop are very similar to the ones just

described near Nawegaon. An excellent example of the type of rock prevailing here is shown in Plate 14, figs. 1 and 2. The former is a general view of the rock, while the latter is taken much nearer with a specially adapted camera pointing vertically downwards. In this type of rock the intrusive character of the acid bands with reference to the rest of the rock is not so obvious as in the rocks described near Nawegaon. Nevertheless the bands in this exposure are more distinct and separate than they are in the common type of streaky gneiss, and this type of rock occupies an intermediate position between the rocks described at Nawegaon, in which the intrusive nature of the acid bands is clear, and the common type of streaky gneiss in which all evidence of origin has become lost.

Although the rock described above may not in itself provide evidence as to its origin, examination of other outcrops further down-stream shows that not only are the fairly thick and well separated bands intrusive into and distinct from the rest of the rock, but many of the finer bands as well. Some of these latter can be seen thickening laterally and broadening out into one of the more obvious intrusive bands.

At other places in this same outcrop the rocks have a comparatively small number of acid bands, resembling some of the rocks in the exposure near Nawegaon, of which photographs have been given. Here also it is possible to see the original rock into which the acid magma was intruded. It is a medium-grained biotite-granulite, exactly like the rock at Nawegaon.

At the western end of this outcrop a different type of streaky gneiss is found, differing from those already described in containing abundant phenocrysts. Plate 15, fig. 1, shows this type of rock. At first it was thought that the phenocrysts were really *augen* of the acid bands, produced by some kind of rolling-out process. Closer examination, however, showed that they were all phenocrysts, each being a solid crystal of orthoclase, frequently twinned on the Carlsbad law. Although the evidence just here is perhaps not very clear, as can be seen from the photograph, examination of the whole outcrop left no doubt that the phenocrysts belong to the acid bands and not to the rock as a whole. Frequently the acid bands which contain them have become so thinned out in between the phenocrysts that the latter look almost as though they were part of a homogeneous rock. But intermediate stages can be seen which show that this is not so.

## PERMEATION OF METAMORPHOSED SEDIMENTS.

Still confining our attention to those rocks in which the intrusive nature of the aplite bands is clear, the question still remains as to the nature of the rock into which they were intruded. Was it an igneous rock, or was it a sediment? Before discussing this question in detail, reference must be made to two localities which throw some light on the problem.

In the Dhoria *nala*, due north of Bāndara (21° 38′ : 79° 28′), the Mansar stage of the Sausar series is well and typically developed. This stage consists of muscovite-biotite-sillimanite-schists, with or without garnet. Its field relations and its analysis show it to be a metamorphosed sediment,[1] and it is in fact the country rock in which the manganese ore is found in this area. Further up the Dhoria *nala*, west of where the Bāndara-Kursipar road crosses, the Mansar stage is seen to become penetrated by thin veins of aplite, until it is scarcely possible to recognise any resemblance to this stage. Seen alone, away from the unaltered stage, it would not be recognised as belonging to that stage. But the gradual change which takes place in its appearance as the thin aplite bands become abundant is clearly seen in this exposure.

Another instructive case is seen about a mile W. N. W. of Pindkapar. In the Kharkharia *nala* (21° 36′ : 79° 28′ 30″), on the north-west side of the outcrop of the Bichua stage, that variety of muscovite-biotite-schist with coarse muscovite which is a part of the Mansar stage, is seen both in the main *nala* and also in the small tributary from the W. S. W. Up this tributary the same rock becomes intimately penetrated with fine aplite veins. These veins contain a pink felspar and are thus easy to distinguish from the schists in which they occur. Moreover, here and there in the *nala* course pegmatites are seen containing the same pink felspar, and clearly derived from the same source as the thin aplite bands in the Mansar stage. Were it not for the pink felspar betraying the foreign origin of the aplite in which it occurs, the composite nature of the rock as a whole would not have been suspected.

From the descriptions which have been given above of the streaky gneisses seen in various outcrops, where their origin is most clearly revealed, *three main conclusions emerge. One*, that much of the acid banding in the streaky gneisses is of intrusive origin,

[1] *Rec. Geol. Surv. Ind.*, LXV, p. 101, (1931).

and has no immediate connection with the rock in which it occurs. *Two,* that many of the apparently homogeneous streaky gneisses are probably composite. *Three,* that in some cases at any rate the rock which was penetrated was a sediment, and therefore it may have been a sediment also in other cases in which the origin is not so clear.

## THE GRANULITE HOST.

It remains to consider the origin of the original biotite-granulite, seen unpenetrated both near Nawegaon and in the Tundia *nala.*

Under the microscope the rock is seen to be composed of quartz, plagioclase felspar and biotite, with a very little muscovite. There is no potash felspar. Determination of the plagioclase on the Fedorov universal stage shows it to be of the composition 28-30 per cent. anorthite, which is a basic oligoclase. Exact determination was not easy, the felspars being somewhat zoned. Thus one felspar gave 32 per cent. anorthite for the main portion of the crystal, but had an outer zone of composition only 23 per cent. anorthite. Another crystal, almost free from zoning, had a composition of 29 per cent. anorthite for its main portion.

The corresponding unpenetrated rock in the Tundia *nala* is very similar, but has no muscovite. In this rock the felspars are unzoned and have a composition of 32 per cent. anorthite.

In order to obtain further light on the origin of this rock, it was decided to have a partial analysis made. It is not proposed here to go into the question of the value of chemical criteria in determining the origin of metamorphic rocks, since the main arguments are well known. Two large lumps were collected for analysis from the Tundia *nala* and from the Dhoria *nala*; but as they are so alike only one has been analysed. The following result was obtained by Herdsman :—

*Partial analysis of 42·954.*

| | Per cent. |
|---|---|
| $SiO_2$ | 64·25 |
| $Al_2O_3$ | 16·16 |
| MgO | 2·48 |
| CaO | 3·30 |
| $Na_2O$ | 3·40 |
| K O | 2·71 |

It will be seen that we have here an analysis which could easily be that of an igneous rock such as a granodiorite. And though there is no reason why it should not be the analysis of a sediment, there is considerable evidence of a different kind against such a view. It will be shown later that, treated as a whole, these streaky gneisses bear a discordant relation towards the rest of the Sausar series. Now it is unlikely that such a feature would be observed as a result of the intrusion of the aplite band alone. It is much more likely that the aplite bands and the biotite-granulite, which together take the place of the sedimentary succession, are both igneous rocks and together responsible for this observed relationship towards the Sausar series. And so when, in addition, we find the granulite to have a composition which brings it within the range of composition of igneous rocks, we are probably safe in assuming it to have been an intrusive igneous rock.

## MICROSCOPIC EVIDENCE.

The field relations and the chemical analysis have been shown to provide clear evidence as to the origin of these rocks. The microscopic evidence is equally definite.

Microscopic examination of the unpenetrated granulite in the two outcrops near Nawegaon and in the Tundia *nala* shows them both to be free of potash felspar, neither orthoclase nor microcline being seen. But when we come to examine the coarse aplite bands in rocks such as are shown in figs. 1 and 2 of Plate 12, and similar acid veins the intrusive nature of which cannot be doubted, we find them all to be rich in potash felspar. Thus an aplite vein from the Nawegaon exposure is composed of quartz, oligoclase, microcline and orthoclase. A similar vein from the Tundia *nala* is composed of quartz, oligoclase and microcline. Neither biotite or muscovite are seen in either of these veins. The presence or absence of potash felspar then is, in these two exposures, a means of distinction between the older granulite and the later acid intrusive veins. When now we come to examine the streaky gneisses in the same localities, the origin of which is not clear, we find that the biotite-rich bands are free from microcline, while the intervening leucocratic bands are full of microcline. This is well shown in the slide of the rock shown in Plate 15, fig. 2. Naturally there is no sharp junction between the component parts; but the distinction is quite clear. Other streaky gneisses, which are less

clearly banded than this one, show a similar distinction in their component bands as regards the distribution of potash felspar, only it is less well defined.

In short, we have two sets of rocks: (1) unbanded biotite-granulites, and (2) aplites, which can be distinguished by their felspar contents. And then (3) certain other rocks, which in the field seem to be a mixture of these two, are found under the microscope to partake of the characters of both these rocks, as determined by the nature of the felspars. When, further, it is stated that the isolated aplite veins of group (2) are clearly intrusive rocks, having no immediate connection with the rocks in which they occur, then it is a strong presumption that the similar aplitic part of the streaky gneisses is also of intrusive origin. *Thus both the field evidence and the microscopic evidence are strongly in favour of the streaky gneisses which occur in these two localities being composite rocks, formed by the intimate penetration of the granulite by the aplite.*

## MODE OF INTRUSION OF THE STREAKY GNEISSES.

In considering the way in which the streaky gneisses were intruded into their present position, it is necessary to refer to some of the exposures in the Telia *nala*, where it forms the boundary between the Nagpur and Seoni districts, west of the main road.

Near where the road running east from Arjuni (21° 41′: 79° 23′ 30″) crosses the Telia *nala* streaky biotite-gneisses are seen which occasionally contain garnets. The white streaks are coarser and more acid than the rest of the rock, but in most of the exposures they look to be just part of a homogeneous rock. Nevertheless it is difficult to resist the conclusion that there is any essential difference between these thin sheets and the thicker and obviously intrusive aplite sheets which are seen here and there. Here again every gradation can be seen from a rock with only a few such sheets, and those frequently oblique to the foliation, to a rock which seems to be composed almost entirely of these sheets. Such a rock is nearly white in colour. Further down the *nala* the streaks contain phenocrysts of orthoclase, and these are so abundant that the rocks look spotted from a distance.

But in addition to this type of rock, which can be matched elsewhere, an unusual phenomenon is exhibited in an outcrop close to where the Bhatti *nala* comes in from the W. N. W. Here, on

the south side of the river, the acid sheets seem to meet one another as though patches of the rock were discordant to one another. Fig. 2 of Plate 15 shows a part of this outcrop, and was taken with the vertical camera which has already been referred to. A sketch is given here to show exactly what is meant.

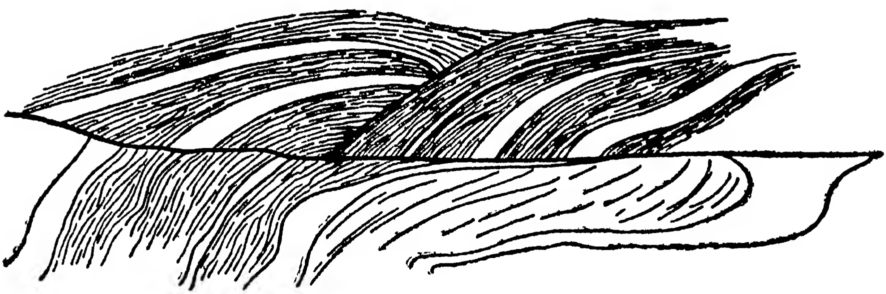


FIG. 1. Diagrammatic sketch of part of Plate 15, fig. 2, showing streaky gneiss with discordant patches.

It is difficult to know how to interpret such a structure. If one assumes that both parts of the rock are igneous, then the aplite sheets may have been intruded into the other part while it was still plastic, and perhaps still undergoing movement, the whole rock being rather mixed up and drawn out. In fact, we seem to have here a case in which the aplite bands were intruded prior to the intrusion of the granulite, a possibility which was suggested on page 346. Some such explanation seems the only possible one, though further examination of this and similar structures may throw light on the problem and provide some different solution.

## RELATION OF THE STREAKY GNEISSES TO THE SAUSAR SERIES.

Finally, we may consider briefly the distribution of these composite gneisses, and their relation to the Sausar series.

Owing to the abundance of the alluvium, which conceals so much of the softer rocks, it is not easy to see from the geological map the structure and relations of the rocks, without a knowledge of the ground. For this reason a simplified map has been prepared, with the alluvium all omitted. This brings out more clearly not only the structure of the rocks, but also the distribution of the composite gneisses and their relation to the Sausar series.

Examination of this map shows at once that these gneisses, treated as a whole, are discordant towards the members of the Sausar series. This relationship is clearly seen just east of the main road, to the north-east of Deolapar, where the whole sequence of the Sausar series gets cut out step by step towards the east, until the gneisses come into contact with the big central outcrop of the Bichua stage.

Of interest as throwing light on the mode of origin of these gneisses, we find near to and west of Belda, and again just north-west of Junewani, relics of the Mansar stage which is seen west of the gneiss outcrop. From this it is to be inferred that the intrusion of the composite gneisses was a tranquil operation, which did not greatly disturb the strata. No doubt much of it was of the nature of peaceful penetration, carried on over a long period, and giving rise in many cases to composite rocks. And such *lit-par-lit* intrusion would clearly be more easily accomplished in rocks already possessing a fissile or schistose structure. It is curious, though, that relics of such a soft rock as the Mansar stage are still found preserved, while tough rocks like the Lohangi stage of banded calc-granulites appear to be entirely missing. It may be that where more massive rocks were encountered, stoping on a large scale occurred; whereas the schistose rocks, which could be intimately penetrated, escaped actual displacement.

## MODE OF FORMATION OF THE STREAKY GNEISSES.

As regards the instrusion of the aplite into the other rocks to produce the streaky gneisses, special conditions must clearly have prevailed to allow of such thorough penetration. In the formation of composite rocks of this nature the invading magma must be in a high degree of fluidity to penetrate so far without consolidation. For this reason one might expect to find the phenomenon commoner amongst basic rocks. This, however, is not the case. Basic and ultrabasic rocks, although less viscous than acid rocks, contain a low volatile content, which is the main factor to be considered. Thus it is that the most typical injection gneisses are to be found in connection with granite magmas, especially with the residual aplitic part, highly charged with water and other volatile constituents at the time of injection.

A further condition which seems to be required is that the whole area must be at a comparatively high temperature. A fluid magma, however much superheated, could not penetrate a cool rock for any great distance. This condition of high temperature is to be expected in an area where the intrusion of igneous magma is at all on a large scale, as was no doubt the case in our own area.

A third condition is that the invaded rock must have a good schistosity already developed, otherwise the igneous magma could not penetrate in the thin parallel bands which are such a feature of these rocks. This condition presupposes that the rock must have already been metamorphosed prior to the later injection. Whether the metamorphism long antedated the injection is immaterial. But intrusion of this nature could only take place under the influence of great shearing stress, and it is permissible to suppose that the stress which was responsible for the intrusion of the aplite was also genetically related to that which produced the regional metamorphism.

We must envisage first a great intrusion of acid magma of the composition of a granodiorite, which displaced the rocks of the Sausar series on a large scale; followed soon after by the intrusion of a more acid aplite phase. This aplite magma was forced into the still plastic granodiorite, and into the softer schistose members of the Sausar series, saturating them with aplitic material, to produce the rocks which we now call the streaky gneisses. In other words the streaky gneisses have been formed partly by the penetration of igneous material by other igneous material, and partly by the penetration of metamorphosed sediment by igneous material.

In this short paper, I have particularly refrained from appealing to work done in other countries, where the conclusions drawn might not be applicable to our own area. In interpreting the geology of a new country the ideal method should be to let the evidence speak for itself, and to draw only such conclusions as are warranted by the facts of the case. Therefore, I have stated the evidence provided by a few particularly clear exposures, and drawn such conclusions as seem to be warranted.

In attacking the problem of the streaky gneisses for the first time, it has seemed best to analyse the simplest case first, where the actual production of a certain type of streaky gneiss can be followed and worked out stage by stage. For this reason only a few exposures have been described in any detail, where the earlier

stages have been laid bare for our examination. If in this way a solution to the simpler problems has been obtained, it will provide a stepping stone for the attack on more complicated problems elsewhere.

## EXPLANATION OF PLATES.

| | |
|---|---|
| PLATE 12, FIG. 1. | Biotite-granulite, penetrated by aplite, near Nawegaon. |
| PLATE 12, FIG. 2. | Biotite-granulite, penetrated by aplite, near Nawegaon. |
| PLATE 13, FIG. 1. | Normal streaky gneiss (specimen No. 42·950), Dhoria *nala*. |
| PLATE 13, FIG. 2. | Biotite-granulite, penetrated by aplite, near Nawegaon. |
| PLATE 14, FIG. 1. | Biotite-granulite, intimately penetrated by aplite, Tundia *nala*. |
| PLATE 14, FIG. 2. | Same as fig. 1, near view from above. |
| PLATE 15, FIG. 1. | Biotite-granulite, intimately penetrated by aplite containing large phenocrysts of orthoclase, Tundia *nala*. |
| PLATE 15, FIG. 2. | Streaky gneiss, showing discordant patches, Telia *nala*. |
| PLATE 16. | Geological map of part of the Ramtek tahsil, Nagpur district (sheet 55 O/6). |

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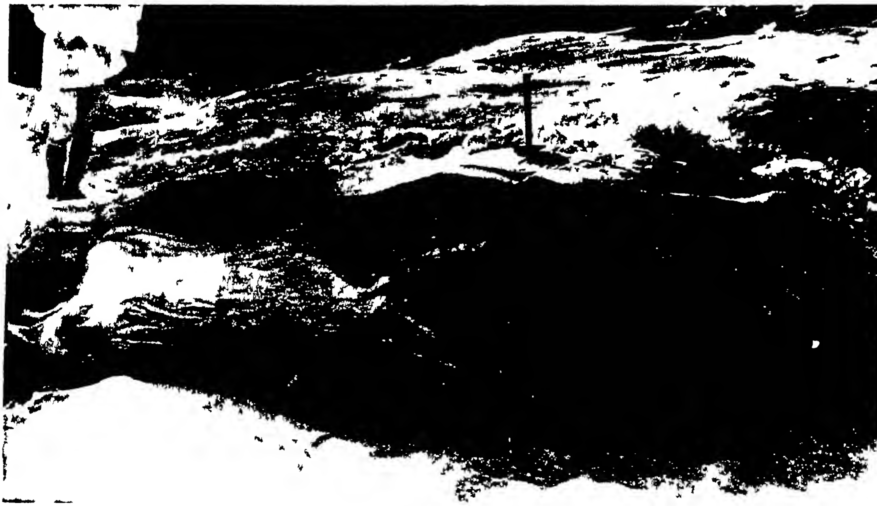
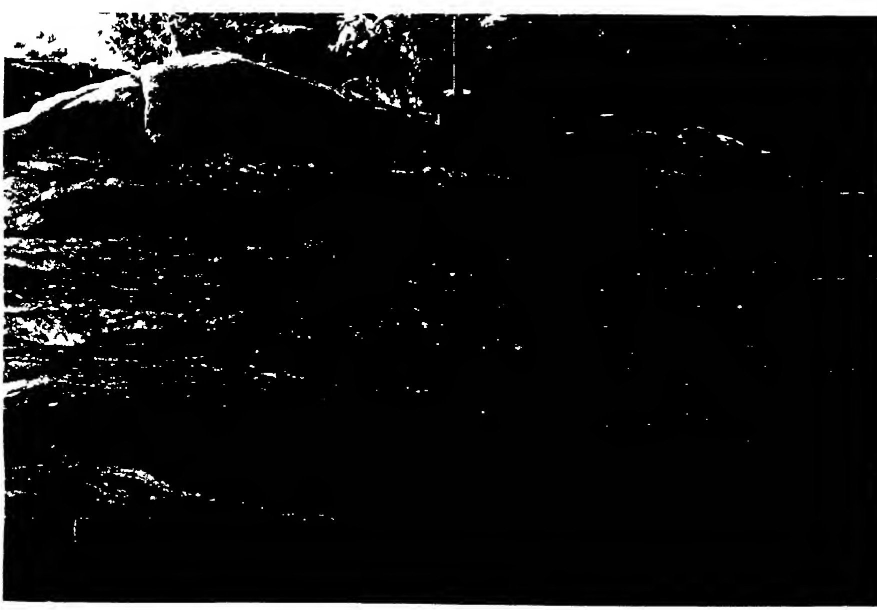


FIG 1 BIOTITE-GRANULITE, PENETRATED BY APLITE, NEAR NAWEGAON



*W D West, Photos* *G S I, Calcutta*

FIG 2 ANOTHER SPECIMEN FROM THE SAME LOCALITY

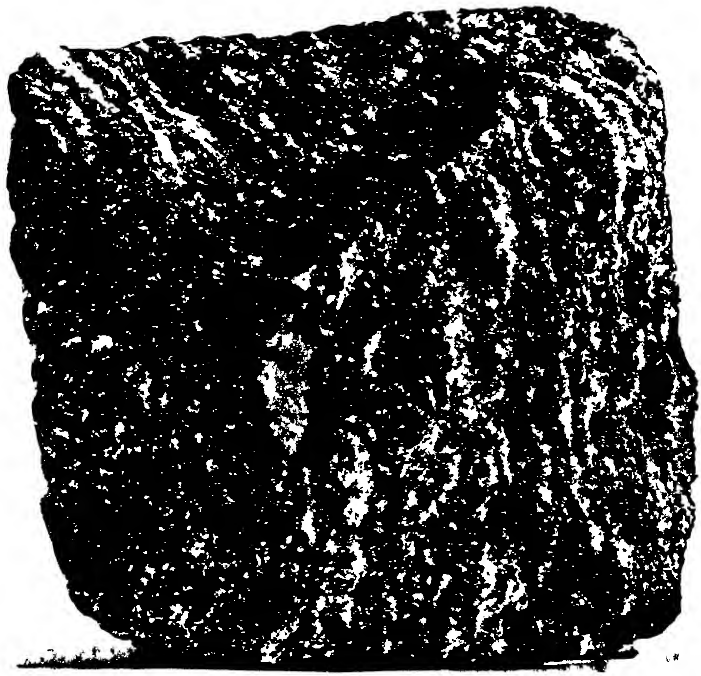
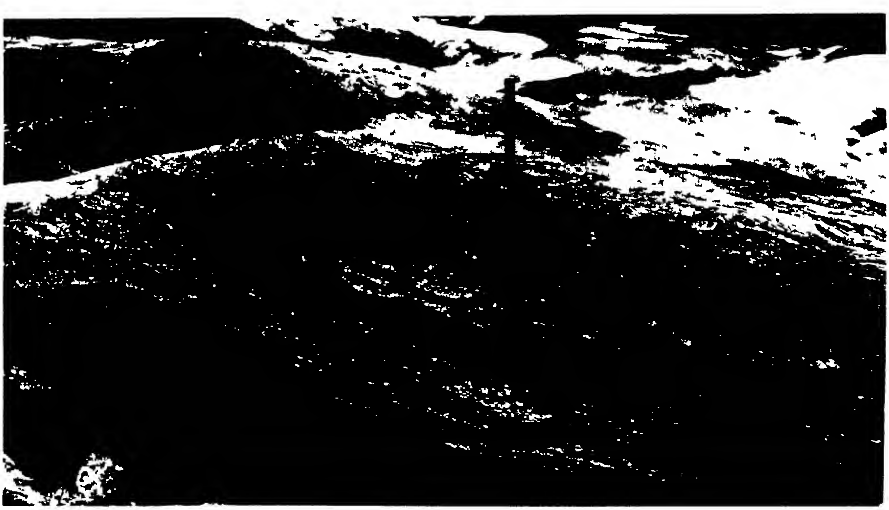


FIG. 1. SPECIMEN (42 950) OF NORMAL STREAKY GNEISS FROM DHORIA NALA.



*P. L. Dutta & W. D. West, Photos.* *G. S. I., Calcutta.*

FIG. 2. BIOTITE-GRANULITE, PENETRATED BY APLITE, NEAR NAWEGAON.

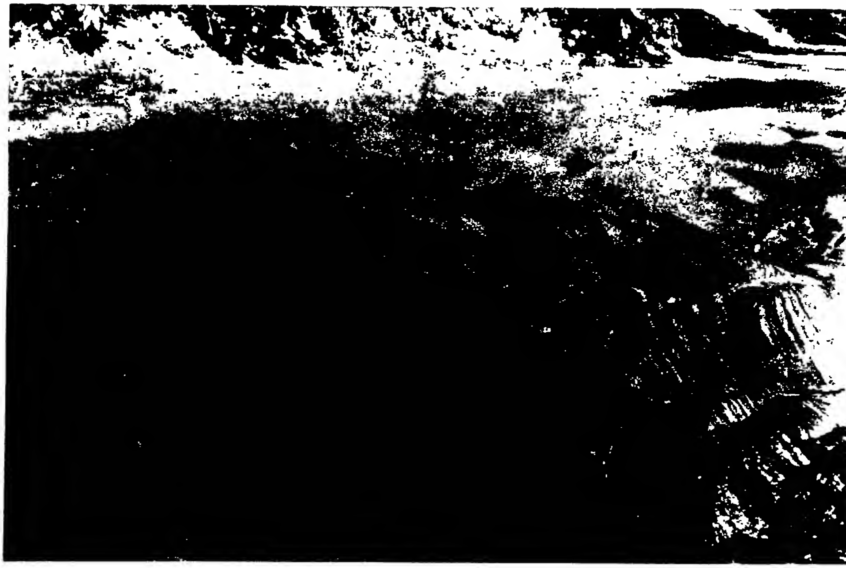
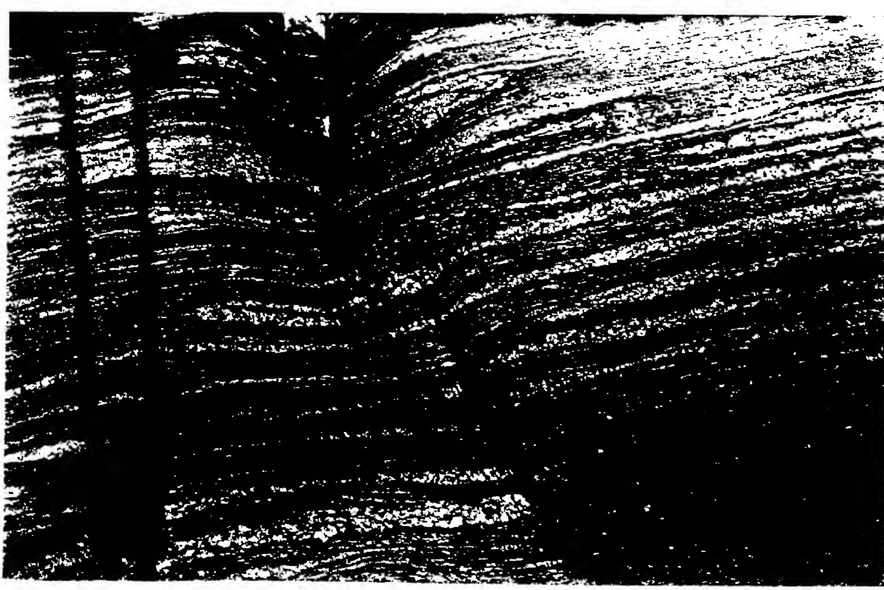


FIG. 1. BIOTITE-GRANULITE, INTIMATELY PENETRATED BY APLITE, FROM TUNDIA NALA.



*W. D. West, Photos.* *G. S. I., Calcutta.*

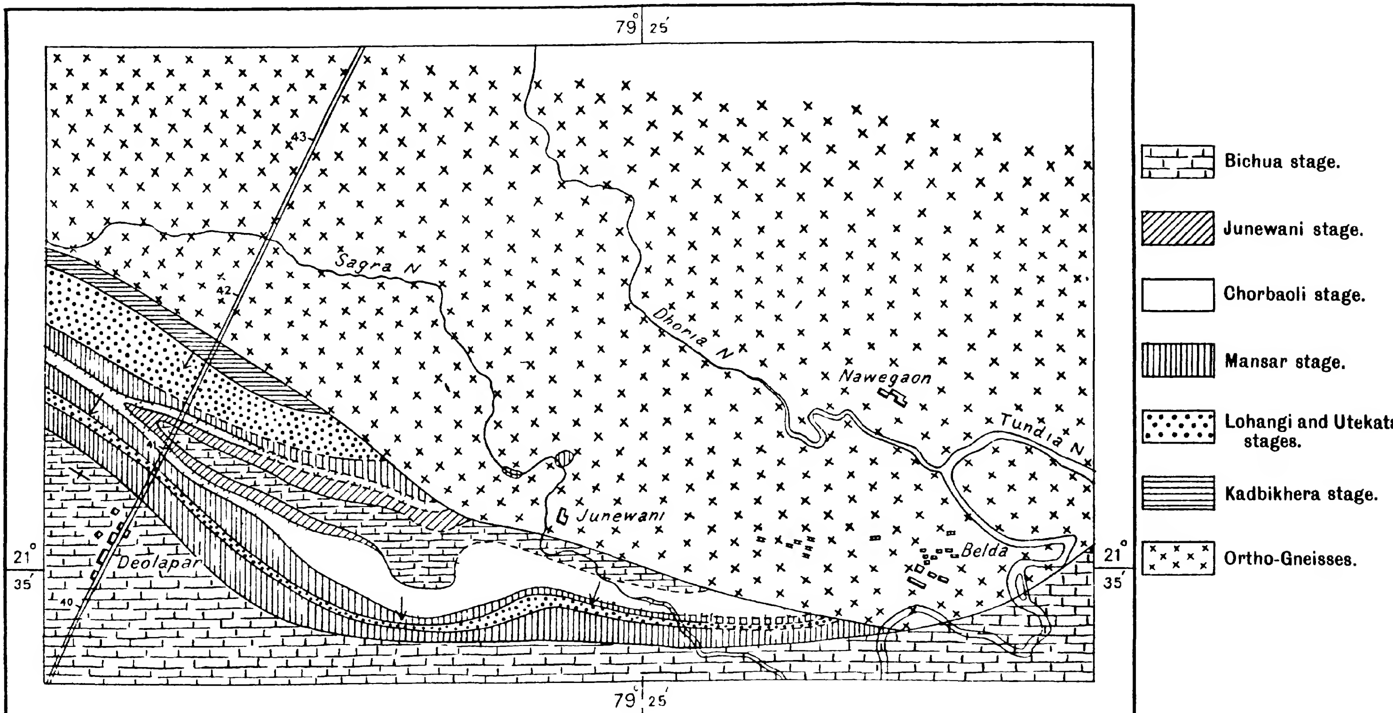
FIG. 2. NEAR VIEW, FROM ABOVE, OF FIG. 1.

FIG. 1. BIOTITE-GRANULITE, INTIMATELY PENETRATED BY APLITE CONTAINING LARGE PHENOCRYSTS OF ORTHOCLASE, FROM TUNDIA NALA.

*W. D. West, Photos.* *G. S. I., Calcutta.*

FIG. 2. STREAKY GNEISS, SHOWING DISCORDANT PATCHES, FROM TELIA NALA.

Records, Vol. LXVII, Pl. 16.




A K Chandra, Del

G S I, Calcutta

GEOLOGICAL MAP OF PART OF THE RAMTEK TAHSIL, NAGPUR DISTRICT (sheet 55 O/6).

*Scale, 1 inch = 1 mile.*

# RECORDS

OF

# THE GEOLOGICAL SURVEY OF INDIA.

**Part 4.]** 1934 **[ February**


## THE GEOLOGY OF THE KROL BELT. BY J. B. AUDEN, M.A. (CANTAB.), *Assistant Superintendent, Geological Survey of India.* (With Plates 17 to 25.)

CONTENTS.

## I. INTRODUCTION.

**Situation.**

The area described in this paper forms a small portion of the lower Himalaya between the Gambhar river, which flows from Simla to join the Sutlej, and the Jumna river, which forms a boundary between Chakrata tahsil and Tehri-Garhwal State.

It lies in the following territories:—Bharauli and Baghat divisions of the Simla Hill States, Patiala State, Sirmur (Nahan) State, and Chakrata tahsil of Dehra Dun district.

The part included in the map (Plate 25) is bounded by latitudes 30° 30′ and 31° and longitudes 77° and 78°. The term *Krol Belt* is taken from Krol Hill, 7,393 feet in height (30° 57′ : 77° 06′), which forms a conspicuous feature of the scenery between Kalka and Simla.

The Krol Belt occupies a narrow strip of mainly limestone country running N.W.–S.E. in its northern part, and changing in strike to nearly E.–W. towards the south.

The highest point is Juin Hill, 8,493 feet. The lowest point is by the Tons river near Kalsi, 1,530 feet. Most of the country lies below 4,500 feet. Two important rivers are the Blaini (Baliana)[1] and the Giri. Solon lies on the watershed between the Indus and the Ganges drainage systems.

**Mapping.**

The area was mapped during the hot-weather seasons of 1928, 1930, 1931 and 1932 and the cold weather of 1933. It is included in one inch to the mile sheets 53 F/1, 2, 5, 6, 10, and 14. Mapping in the Punjab was carried on almost entirely on the now obsolete two inches to the mile Punjab Forest sheets Nos. 312 N.W., S.W., N.E., S.E.; 313 N.E., S.E.; 335 N.W., S.W., N.E. The delineation of topography on these two-inch maps is for the most part astonishingly accurate. The modern one-inch maps are more generalised. Sheets 53 F/6 and 53 F/10 do not coincide properly at their common margin, and geological boundaries at the junction of these two sheets have been slightly adjusted. The whole of the mapping was subsequently reduced to the half-inch to the mile scale.

**Scenery.**

Except for Krol and Sainbar Hills, the greater part of the country between Subathu and Dadahu is devoid of character. Form is seldom seen, most of the hills showing only irregular masses of limestone interrupting the sky-line. E.N.E. of Dadahu a marked change occurs, due largely to the presence of the Tal rocks, which have a sobering effect on the underlying Krol limestones. Views of Guma, 8,098 feet, peak from Nigali Dhar (Plate 18), or of the great semicircle of limestones enclosing Tal rocks at Mishwa, yield examples of true mountain architecture.

[1] The spelling on the modern maps is *Baliana*. The term *Blaini* has become so fixed in Indian geological nomenclature that it should not be altered. It was written *Blini* by Medlicott.

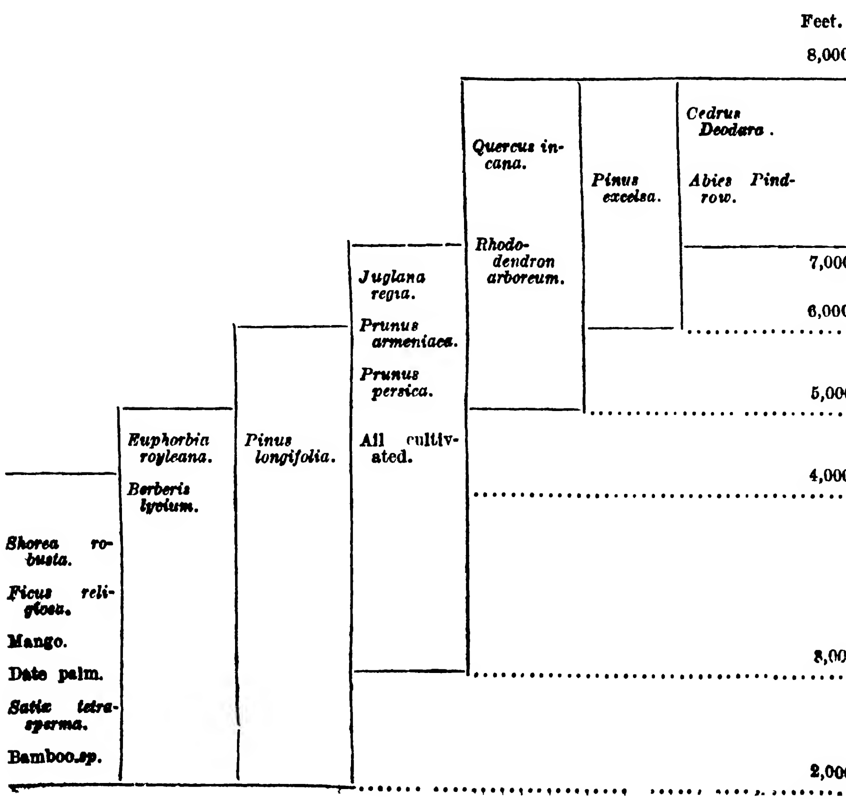
**Climate.**

Above 5,000 feet the temperature remains comfortably cool. Below 4,000 feet, during the months of April, May and June, climatic conditions are tropical. At this time of year the densely jungle-covered river valleys are hot, humid and unpleasant.

**Flora.**

The flora of the plains persists up to 4,000 feet. The dominant tree of the lower Himalayan foothills, particularly on sandy and shaly soils, is the *chil* or *chir* pine, *Pinus longifolia*. Higher up comes the oak-rhododendron association. The cedars and firs are rarely seen along the Krol Belt, being found only on the northern slopes of Guma and Juin peaks. The following is a table of the prominent shrubs and trees, with approximate altitude limits, for the area visited.

*Table of Trees and Shrubs, with approximate altitude limits of growth.*



**Acknowledgment.**

The writer is particularly indebted to Mr. W. D. West, who introduced him to the geology of the Simla hills, and who, together with Mr. D. N. Wadia, has discussed many of the questions brought forward in this paper. To Col. Sir S. R. Christophers, F.R.S., Director of the Research Institute, Kasauli, he is grateful for hospitality and for information concerning the Tertiary rocks. Finally, the assistance given by His Highness the Maharaja of Nahan State, and by the Sirmur Durbar, should be recorded.

## II. PREVIOUS WORKERS.

**H. B. Medlicott.**

The first authoritative work was that of H. B. Medlicott in 1864[1], who described a tract of the Himalaya, 230 miles in length and 7,000 square miles in area, between the Ravi and Ganges rivers. Medlicott's attention was confined principally to the Tertiary rocks, but his observations on the pre-Tertiary rocks have formed the basis of all later work.

Though dividing up these latter rocks into metamorphic and unmetamorphic, Medlicott tended to correlate together those showing different degrees of metamorphism. His classification was as follows :—

*Sub-Himalayan series.*

| | | |
|---|---|---|
| Upper | Sivalik | |
| Middle | Nahun | |
| Lower | Subathu | Kasaoli.<br>Dugshai.<br>Subathu. |

*Himalayan series.*

1. Unmetamorphic.
   - Krol.
   - Infra Krol.
   - Blini.
   - Infra Blini.
2. Metamorphic.
   - Crystalline and sub-crystalline rocks.

While the Infra-Krol and Krol rocks on Krol Hill are practically unmetamorphosed, Medlicott considered that their equivalents at Simla were crystalline schists, tremolite-limestones and recrystallised quartzites.

[1] *Mem. Geol. Surv. Ind.*, III, (1864).

In spite of the great area he covered, the wealth and detail of observation are remarkable, and Medlicott's memoir will for all time remain a classic.

Between 1883 and 1888, R. D. Oldham published a series of papers in the *Records*[1], on the geology of the hills between Simla and Chakrata. He was concerned chiefly with the Blaini and Infra-Blaini rocks and his work showed the difficulties which confront any detailed examination of complicated mountain areas.

**R. D. Oldham.**

In his second paper (cited below), he suggests a glacial origin for the Blaini conglomerate, re-naming it a *boulder slate*. In his fourth paper, he assigns an Upper Palaeozoic age to these beds.

From 1885 onwards, C. S. Middlemiss mapped and described large areas of British Garhwal.[2] From the point of view of this present account, his second paper, on the physical geology of West British Garhwal, is the most significant, since that tract of country lies to the south-east of, and in strike continuation with, the Krol Belt. A new standard of accuracy in mapping was there introduced, and the possibility of great rock translations was foreshadowed. Middlemiss paid particular attention to metamorphic condition, noticing transitions between rocks of widely different metamorphic grade.

**C. S. Middlemiss.**

Middlemiss worked later in the Hazara area, many of the rocks and structures of which are probably equivalent to those of the Krol Belt.[3]

In 1888-1889, R. D. Oldham surveyed the country bordering on the then projected Kalka-Simla railway. His results were written up in manuscript form, but were never published. His mapping of the Tertiaries is of great accuracy, but he did not bring out the complexity of the pre-Tertiary rocks. He accepts the correlations of Medlicott.

In 1908, Sir Thomas Holland described a striated boulder from the Blaini beds at Simla, remarking that the find added weight to Oldham's supposition of a glacial origin. He suggested a Purana age for the Blaini.[4]

[1] *Rec. Geol. Surv. Ind.*, XVI, pp. 193-198, (1883); *op. cit.*, XX, pp. 143-153, (1887); *op. cit.*, pp. 155-161, (1887); *op. cit.*, XXI, pp. 130-143, (1888).

[2] *Rec. Geol. Surv. Ind.*, XVIII, pp. 73-77, (1885); *op. cit.*, XX, pp. 26-40, (1887); *op. cit.*, pp. 134-143, (1887); *op. cit.*, pp. 161-176, (1887); *op. cit.*, XXI, pp. 11-28, (1888). *Mem. Geol. Surv. Ind.*, XXIV, (1890).

[3] *Mem. Geol. Surv. Ind.*, XXVI, (1896).

[4] *Rec. Geol. Surv. Ind.*, XXXVII, pp. 129-135, (1908-09).

**Prof. H. C. Das-Gupta.**

Between the years 1915 and 1918, Prof. H. C. Das-Gupta, of the Presidency College, Calcutta University, led parties of students on excursions in the Solon and Simla neighbourhood. Prof. Gupta published various papers on the age and correlations of the rocks in this area.[1]

**G. E. Pilgrim and W. D. West.**

In 1925, G. E. Pilgrim and W. D. West initiated a detailed survey of the Simla Hills, using the excellent two-inch to one mile Punjab Forest maps.[2] Their area lies adjacent to and north-east of that described in the present paper. Their work was confined almost entirely to the more metamorphosed rocks. They realised that the apparent simplicity of the sections at Simla was probably deceptive, and, discarding the correlation of the rocks at Simla with those on Krol Hill, they suggested instead that a series of thrusts had brought rocks of different degrees of metamorphism to lie in abnormal juxtaposition. Their succession is as follows:—

| | |
|---|---|
| Dagshai series | Lower Miocene |
| Subathu series | Middle Eocene to Upper Oligocene |
| Krol series | ? |
| Krol sandstone | Lower Gondwana |
| Infra-Krol beds | Lower Gondwana |
| Blaini limestone | Lower Gondwana |
| Blaini conglomerate | Lower Gondwana |
| Simla series (Infra-Blaini) | Lower Palaeozoic |
| Jaunsar series | Purana |
| Chail series | Purana |
| Jutogh series | Archaean ? |
| Shali limestone and slates | Position un-ertain. |

The sequence of the Jutogh, Chail, Jaunsar and Simla series was according to metamorphic condition, the most metamorphosed being regarded as the oldest. Since these series occur in such a manner

[1] *Journ. As. Soc. Beng.*, N. S., XIV, p. clxxxv, (1918). *Journ. Dept. Sci.*, VIII, (1926), Calc. Univ. Press; *op. cit.*, X, (1929).
[2] *Mem. Geol. Surv. Ind.*, LIII, (1928).

that the most metamorphosed rocks lie at the top, the more altered series were regarded as being founded upon thrusts over those that are less altered, as follows :—

*Ascending sequence* ↑ .

Jutogh series.
——————————— *Jutogh thrust.*
Chail series.
——————————— *Chail thrust.*
Jaunsar series
——————————— *Jaunsar thrust.*
Autochthonous sequence of Simla slates to Krol rocks.

The existence of thrusts was indicated, independently of metamorphic condition, by disappearance of rock divisions owing to overlap.

An Upper Carboniferous age was re-introduced for the Blaini beds.

D. N. Wadia.

In 1928, Mr. D. N. Wadia gave an account of the geology of Poonch State and adjacent portions of the Punjab. In this memoir[1] he shows the existence of extensive thrust planes, and of volcanic rocks in the Upper Carboniferous and Permian. Thrust-planes are still more emphasised in later papers by Wadia, particularly that on the Himalayan syntaxis.

Work has been continued in the Simla hills by Mr. West and myself, summaries appearing in the Director's *General Reports.*[2] The writer has published a Miscellaneous Note on the supposed occurrence of *Chonetes* in the Krol limestone and a short paper on the age of certain Himalayan granites.[3]

Nature of paper.

The present paper is a continuation of the work started by Pilgrim and West. Some of the views put forward here differ slightly from those previously expounded. Areas have been examined which had not been formerly visited, and from the study of which modified interpretations have arisen. In no sense can these present opinions be considered final. They are put forward for the purpose of crystallising out the information and deductions before the collected data becomes too unwieldy. In regions of such complexity, modification is bound to result from continued work and fuller knowledge, but the later work is only a growth from that which has preceded, and is dependent on it.

[1] *Mem. Geol. Surv. Ind.*, LI, Pt. 2, (1928). *Rec. Geol. Surv. Ind.*, LXV, p. 189, (1931).
[2] *Rec. Geol. Surv. Ind.*, LXII, pp. 164-168, (1929); *op. cit.*, LXV, pp. 125-132, (1931); *op. cit.*, LXVI, pp. 125-130, (1932).
[3] *Op. cit.*, LXV, pp. 534-536, (1931); *op. cit.*, LXVI, pp. 461-471, (1933).

## III. SEQUENCE OF FORMATIONS IN SIMLA-CHAKRATA HILLS.

*Stratigraphical sequence.*

| Age. | Solon neighbourhood. | | | Tons river neighbourhood. | | |
|---|---|---|---|---|---|---|
| Miocene | Nahans (only at Kalka) | | | Nahans | | |
| Lower Miocene | Kasauli<br>Dagshai | | | Dagshai | | |
| Oligocene<br>Eocene | Subathu (Nummulitic) | | | Subathu (Nummulitic) | | |
| | | | | *never in contact.* | | |
| ? Cretaceous and Jurassic | *absent.* | | | Tal | Upper Tal | |
| | | | | | Lower Tal | |
| ? Permo-Carboniferous | Krol series | Krol limestone | Krol E | Krol series | Krol limestone | Upper Krol limestone |
| | | | Krol D | | | |
| | | | Krol C | | | |
| | | | Krol B (Red Shales) | | | Red Shales |
| | | | Krol A | | | Lower Kro limestone |
| | | Krol sandstone | | | Infra-Krol | |
| | | Infra-Krol | | | | |
| Upper Carboniferous | Blaini | | | Blaini | | |
| ? Devonian and Silurian | Jaunsar with possible Mandhali | | | Nagthat stage<br>Chandpur stage<br>Mandhali stage | Jaunsar series | |
| ? Lower Palaeozoic and pre-Cambrian | Simla slates with Kakarhatti limestone | | | Deoban limestone<br>Simla slates (Morar-Chakrata beds) | | |
| Miocene [and older] | Dolerites | | | | | |

## IV. LITHOLOGY.

The lithological characters of the various rock divisions will now be described, irrespective of whether correlation will ultimately render some of them equivalent. Beginning with the base of the succession are the Simla slates.

## Simla Slates.

The Simla slates occur typically on the spurs between Simla and the Sutlej river. In the Krol Belt, they are seen in a stretch of country which runs from the Gambhar river, past Kandaghat and along the Ashmi-Giri rivers. They also occur in the vicinity of Subathu and Solon. After a long gap, they crop out again between Morar, Chakrata and the Jumna river, north of the Tons thrust.

The Simla slates are dark- and sombre-coloured, with grey-blue tints, and are made up of micaceous shales, bleaching shales and slates, pencil slates, clay-slates, occasional phyllites, sandstones and predominant graywackes. Except for fracture cleavage in some of the shale bands between the more massive graywackes, true oblique cleavage is never seen. Parting is parallel to the bedding planes. Bedding thickness varies from ten feet to half an inch, but is characteristically massive.

### AREAL TYPES.

*(a) North-east of the Krol thrust.*

**Chhaosa type.**

The Chhaosa slates are similar to those found north of Simla. They occur in massive beds, two and more feet in thickness. Graywackes predominate over slates. The most characteristic feature of the Chhaosa slates is the occurrence of numerous beds containing pillow- and kidney-shaped concretions, up to 18 inches in length, of impure quartzite and clay-slate set in a clay-slate matrix. The difference in composition between the concretions and the matrix is often very small. Many of the pillow-concretions are too flat for their origin to be explained by rolling and concentric accretion on an inclined floor. Possibly earthquake shocks jolted partly consolidated material amongst overlying softer muds that had been just previously deposited. Wash-outs may be seen, as in the Ashmi river below Sunny. Current-bedding is common, especially in the more quartzitic rocks, and in the Gambhar river shows the beds to be uninverted.

This division generally occurs in cliffs. The base is not seen. Its visible thickness is 1,400 feet in the excellent exposure along the Gambhar river.

Domehr slates.

The Domehr slates are thin-bedded and consist of soft, green, micaceous silts, gritty slates, cindery and nodular micaceous sandstones. Ripple-marking is very common. There is a complete lack of metamorphism. This division succeeds the Chhaosa slates and has a minimum thickness along the Gambhar river of 1,200 feet. It has not been recognised east of Kandaghat.

### (b) *South-west of Krol thrust.*

Between Subathu and Arki, the Simla slates are richer in puckered leafy phyllites, but they exhibit as well some massive quartzitic bands, finely ripple-marked shaly quartzites and green nodular micaceous siltstones.

Kakarhatti limestone.

The chief feature of these slates is the intercalation of the Kakarhatti limestone. This is pale grey, blue-grey and purple in colour. It is microcrystalline and sometimes oolitic, whence its pseudo-organic appearance. Chert is abundant, in crinkled thalloid patches more or less parallel to the bedding. The limestone has been strongly strained and has sometimes flowed. It is associated with soft, green, needle shales and bleaching slates. It has been traced by Dr. Pilgrim from Subathu to Arki and must continue for at least five miles further north.

### *Microscopical.*

There is no hard and fast line between sandstones, graywackes and slates. The finer slates, of grain-size less than 0·02 mm, are too obscured by clay-paste and dirt for determination (21959). In less fine-grained rocks, authigenic quartz, chlorite and sericite may be seen. The grain-size of the sandstones seldom exceeds 1·0 mm, being usually about 0·25 mm. Detrital grains of phyllite, quartz, muscovite, plagioclase (19203), tourmaline (21961) occur in a matrix with authigenic quartz, chlorite and sericite. Chlorite is common, in minute rods and bundles set in quartz (19204), as film-envelopes to grains (19211), or in patches (19204). Secondary sericite may occur in laths up to 0·25 mm long. Carbonate is rare (19205).

*Kakarhatti limestone.*—Concentric rings of carbonate occur round cores of more crystalline carbonate. Interstitial between the ooliths is a matrix of carbonate, detrital quartz, plagioclase and white mica. Of interest is the intimate authigenic association of quartz and carbonate in the ooliths. Good prism sections of quartz, with rhombohedral terminations, may be seen showing euhedral boundaries adjacent to and penetrating the rings of carbonate. Inside this authigenic quartz are

granules of carbonate which either are unreplaced remnants or represent incipient crystallisation of carbonate simultaneously with quartz. Authigenic chlorite is also common with sharp boundaries and fresh appearance (21956, 21958).

## Jaunsars.

The Jaunsars are provisionally regarded as comprising three stages, in apparent ascending order :—The Mandhali stage ; the Chandpur stage ; and the Nagthat stage. These stages were only properly differentiated after this report had been written.

### (*a*) *Mandhalis* (*Lower Jaunsar*).

A discussion of this difficult group of rocks is postponed till a later section (page 419). Here I shall assume as Mandhalis those beds which apparently underlie the Chandpur stage (Middle Jaunsars), and overlie, by thrust junctions :—

(*a*) Nahans and possible Dagshais on the south side of the Jaunsar syncline ;

(*b*) Simla slates, with or without Nummulitics, on the north side of the Jaunsar syncline.

The apparent succession on both sides of the syncline is more or less the same, and is given below.

| *South limb.* | *North limb.* |
|---|---|
| dips north. | dips south. |
| Chandpur stage. | Chandpur stage. |
| White massive quartzite. | White massive quartzite or quartz-schist. |
| (*g*) Bansa limestone, sporadic. | Bansa limestone, very persistent. |
| (*f*) Slates and phyllites. | Slates and phyllites. |
| (*e*) Dhaira (30 33′ : 77 50′) limestone. Locally graphite-schist. | Khambroli (30 38′ : 77 50′) limestone. Locally graphite-slate. |
| (*d*) Boulder bed. | Boulder bed. |
| (*c*) Quartzites, grits and conglomerates. | Quartzites, grits and conglomerates. |
| (*b*) Kalsi limestone or marble. | Naraya (30 39½′ : 77 50½′) limestone or marble. |
| (*a*) Kalsi quartzites and bleaching slates. | *absent.* |
| *Krol thrust*, dip north. | *Tons thrust*, dip south. |
| Nahans, possible Dagshais | Nummulitics, possible Dagshais, resting on Simla slates. |

(*a*) The Kalsi quartzites and bleaching slates may be seen on the hill half a mile W.S.W. of Kalsi post office and on the lower slopes of the hill-sides east of the Amlawa *nala.* The quartzites are dull grey-white, and highly veined with quartz. The slates are only seen in a weathered condition, being bleached and stained with iron oxides.

(*b*) The Kalsi limestones are most easily seen near the foot-bridge over the Amlawa *nala*, half a mile north of Kalsi post office, and on the col between hills 6,925 and 6,658 feet, south of Kailana.

They are highly banded and interbedded with slate or phyllite. Colours are variable—grey-blue, green, purple and variegated purple-white all being seen. A sandy basis is rare. When unstressed, the limestones are microcrystalline, but stress has commonly led to the formation of fine-grained marbles, which are sometimes visibly crystalline. Specimens from the same locality may be unfolded or highly contorted.

A feature which has occasionally been noticed, as, for example, one mile E. S. E. of Mandharsu, is that the apparent bedding-planes of this limestone are in reality joint-planes, since the composition bands, which give the true bedding, may be seen to cut these planes at high angles.

(*c*) The overlying quartzites, grits and conglomerates may be well seen just upstream from the footbridge over the Amlawa *nala* on the banks of the Jumna river, by mile 33 along the Chakrata-Mussoorie mule-track and at Dagura. Conglomerates are rare, but pebble beds containing pebbles of vein-quartz and purple slate or phyllite are common. Colours are pale green, grey and purple. The rocks are strongly ripped with vein-quartz, and are generally sheared to give schistose quartzites, and pebble-schists. Chlorite is the chief mineral developed, which imparts the dominant pale green colour. These schistose quartzites often weather into soft rocks that belie their real metamorphic nature, a consequence possibly of the ease of water permeation along the incipient planes of schistosity. There results an anomalous feature in that the Nummulitic quartzites, found locally at Dabra close to the Mandhalis, are vitreous, and appear superficially to show greater metamorphism than the weathered Mandhali quartz-schists.

(*d*) The boulder bed occurs almost invariably above these pebbly quartzites and just below the Dhaira limestone. There may be other boulder beds, but it is impossible to tell to what extent folding and faulting may have displaced the original succession and

have resulted in duplication of some beds with elimination of others that were formerly adjacent.

The best localities for seeing these rocks are in the Jumna river 700 yards W.S.W. of Bias, in the Tons river near the thrust contact of Mandhalis with Simla slates, a quarter of a mile S.S.W. of hill 6,571 feet, and in a *nala* half a mile south-east of Makhta. The matrix is either slate, gritty slate or pure sandstone. Boulders and pebbles consist characteristically of limestone, dark slate, pale and dark sheared quartzites, and vein-quartz. Limestone fragments are invariably present in these rocks, in contrast to their rarety in the boulder bed of the Blaini. The limestones are either dark and microcrystalline, or marmorised to white, speckled, fine-grained marbles, similar to the marmorised type of the Kalsi limestone. Occasionally pink-weathering limestones are also seen. Together with these limestone fragments, there are very frequently found slivers of dark limestone that grew *in situ* in the rock. In the Tons river, these slivers may be seen to be up to 3 feet 6 inches in length. They are never over two inches thick. It is impossible to assume that such flat plates of limestone were deposited as fragments derived from erosion of pre-existing limestones, since they would have fractured in transport. Stress has certainly caused elongation of some of the fragments of limestone and quartzite, but the dimensions of these slivers are such that they cannot be accounted for solely by stress-elongation. Further, lenticles of sandstone of similar type to the limestone slivers, are also found grading insensibly into a sandstone matrix containing boulders. The whole aspect of these rocks is that of original lenticular deposition of primary and derived constituents.

Immediately below the Dhaira limestone is sometimes seen a graphite-schist or slate. The clearest exposures are in the Jumna river, 700 yards W.S.W. of Bias, where graphite-schist intervenes between boulder bed and limestone, and in the Shwala *nala*, 0·67 miles west of Maralhau, where there is an abrupt contact of graphite-slate containing lenticles of carbonate and the overlying limestone.

(*e*) The Dhaira limestone is made up of thinly interbedded, dark, microcrystalline limestone and dark pyritic slate. The limestone is often lenticular and may closely resemble the Lower Krol limestone. It differs from the latter, however, in its greater degree of interbanding with slate, in its markedly angular folds, and in its frequently sandy basis. This limestone may be seen on the south side of the

Jaunsar syncline at Pathna, north of Badhana, hill 3,993 feet, Dhaira, and in the Jumna river at Bias. On the north side of the Jaunsar syncline, it is to be seen between Ara and Khambrali, near Uproli, and south of Dagura.

(*f*) Between the Dhaira and Bansa limestones occur silvery black, sheeny phyllites and pale green, slightly talcose phyllites. These are best seen north of Udpalta.

(*g*) The Bansa limestone is very distinctive since it weathers to deep blue-black, granular surfaces, showing abundance of sand grains. On fracture the limestone is almost invariably eu-crystalline and blue in colour, though grey and purple colours are sometimes seen. The bedding is coarse, though the individual beds may be seen to be made up of many bands of slightly varying sand content. This sand content is far greater than that of the Dhaira and Kalsi limestones, from which the Bansa limestone is also distinguished by its more massive bedding.

On the north limb of the Jaunsar syncline, the Bansa limestone has been traced almost without interruption for 24 miles and has been an invaluable horizon. Along the southern limb of the syncline it is inconstant, though it occurs intermittently from just north of Chandni to a short distance east of the Kalsi-Chakrata motor road after which it is, for some reason, cut out.

Intimately connected with the Bansa limestone and often interbedded with it, is a pale quartzite or quartz-schist. This has been placed as the bottom member of the Chandpur stage, though the division should not be taken to imply any break in sedimentation.

### (*b*) *Chandpur stage* (*Middle Jaunsar*).

The rocks of this stage form a distinctive outcrop from Chandpur, past Naga Tibba, Chorani, and extending eastwards to Nag Tibba in 53 J/N.W.

The most characteristic features of this stage are a highly banded association of quartzite and phyllite, and the presence of abundant green beds. As many as 24 bands of quartzite and phyllite may be seen in two centimetres. Although quartzite is really in excess of phyllite, the latter appears to predominate since it invariably adheres as thin films to the surfaces of the quartzite. The true ratio is seen in sections at right angles to the bedding. As a result of compression, this quartzite-phyllite association is generally thrown into striking crinkles and fold-puckers, which, together with the small-scale

banding, result in simulation of fossil wood. The puckers resemble ripple-marks, but are usually too regular and of too accentuated amplitude actually to be so. True ripple-marks do occur in the quartzite bands, which impart to the later deposited muds, now phyllite, the same relief, but in such cases the amplitude is in keeping with that of ripple-marks. Later compression may, of course, fold these sedimentation ripples into puckers.

The phyllites grade into sheeny schistose phyllites, which just lack a sufficient degree of metamorphism to be called true schists. Such schistose rocks are used as roofing material at Manogi, wrongly called Dikroli, in 53 J/N.W.

Besides this dominant quartzite-phyllite association, there are more massive current-bedded quartzites and an extensive series of chlorite-tuffs, slates and quartzites. These green rocks occur in distinctive homogeneous beds, showing strong polygonal jointing, and brown crusty weathering. Fracture is with a sonorous 'hammer' ring.

The majority of these rocks are metamorphosed tuffs, though occasionally amygdaloidal basic lavas are found as along the Mussoorie-Chakrata mule-path between miles 20 and 22. The differentiation in the field between tuff, lava and fine-grained intrusive rock (? contemporaneous with the volcanic material) is often very difficult. The coarser dolerites are, of course, readily recognisable.

There is no doubt about the pyroclastic and volcanic nature of the green rocks themselves. It is possible, however, that much of the so-called quartzite-phyllite association may also be tuffaceous. Many of the quartzitic bands under the microscope show little clastic quartz, but solely a fine-grained mosaic of quartz, sericite and chlorite, similar to that found in the undoubted tuffs. I am indebted to Dr. J. A. Dunn for drawing my attention to this possibility, and to references to photographs of the highly banded, recent, sub-aerial tuffs in New Zealand.[1]

The thickness of this stage near Chorani and Nagthat is at least 4,500 feet.

### (c) *Nagthat stage (Upper Jaunsar).*

The Nagthat stage was only recognised as a separate group in 1933, after this paper had already been written. West of the Tons,

[1] *Bull. N. Z. Dept. Scientific and Industrial Research*, No. 32, (1932).

it was not differentiated by mapping from the underlying Chandpur stage, though it is undoubtedly represented by outcrops in the Tons river below Andra, and at Minal Bag.

In the present map it is well seen on Nagthat Hill and by Lakhwar, but the best development is to the east, in sheets 53 J/N.W. and J/S.W.

The characteristic rocks are sandstones, arkoses, quartzites, grits, conglomerates, clay-slates and phyllites showing purple and green colours. Some of the sandstones are pyritic, weathering to rusty bleaching crusts. The arenaceous rocks are strongly current-bedded and ripple-marked. The conglomerates contain pebbles of vein-quartz, often stained red or purple, purple and pale quartzites, purple and green slate or phyllite. They are typical of the Jaunsar conglomerates of the Simla area. Green tuffaceous sandstones are developed east of the area included in the map.

Boulder beds have been found in probable Nagthat beds in two places. One exposure is on the hill-side 0·4 miles N.N.W. of Hiyun; the other exposure is in the Tons river 0·7 miles south-west of Altau. In both localities, the boulder beds are associated with quartzites, slates and phyllites, while in the Tons locality, there are also dark micaceous slates of Infra-Krol type. No limestones were seen. The boulders are angular, and consist of dark slate and greenish quartzite, types common in the Jaunsars. The matrix is gritty. Other boulder beds occur in what is definitely the Nagthat stage, south of the Aglar river in sheet 53 J/3.

In the Newali *nala*, immediately to the north-east of Khadayat, are found green tuffaceous quartzites, some of which are agglomeratic, and resemble the gritty facies of the Blaini when relatively free from pebbles and boulders.

Great variation in metamorphic condition occurs. Some of the rocks are soft clay-slates and sandstones. Others are talcose phyllites and schistose quartzites.

The rocks of this stage appear in the north to lie conformably upon the Chandpur stage, often with a basal conglomerate (Nagthat Hill). Towards the south it is probable that they overlap the Chandpur stage with marked unconformity. The significance of this unconformity is not at present fully understood.

### *Microscopical.*

When unaltered, the arenaceous rocks of the Jaunsars are generally more or less pure quartzites, with or without plagioclase and tourmaline. Grain-size

averages 0·50 mm. within limits, in the specimens examined, of 1·7 mm. and 0·20 mm. The feldspar is almost always plagioclase, near the albite end (21978, 21967). Tourmaline is generally common (21977, 21967). The cement is silica. Increase of strain may be seen by the following progressive symptoms :—

(1) Extensive strain shadows, (19196, 21967).

(2) Breaking up of the clastic grains by frittering along the margins and formation of sericite quartz mosaic continuous with the grains. Strain shadows marked (21966, 21978).

(3) Greater proportion of matrix formed by break-down of the grains. Marked frittering and straining (21963, 21977). Clastic structure discernible under low-power and in ordinary light.

(4) Grains isolated in a crush matrix of sericite and quartz, chlorite and quartz, or chlorite, sericite and quartz. The original rounded clastic grains have lost their original contours and become angular, with frittered edges intimately associated with the pulp matrix (21976, 19197, 21969, 21970). In the hand specimen, some of these quartzites are markedly schistose (44·103).

(5) Matrix more common than grains and clastic origin just discernible under low-power. No original edges to grains.

$\left.\begin{array}{l}21972\\21973\end{array}\right\}$ chlorite-sericite-quartz-schist

21964 chlorite-sericite-magnetite-quartz-schist.

Not all the matrix of some of these rocks is secondary in origin, formed by the break-down of grains. Some of it is primary, being the finer-grained clayey matrix that surrounded the grains of quartz and feldspar. It is difficult in cases of obvious reconstruction, in which break-down is manifest, to determine the proportion of primary and secondary matrix, since both yield a fine-grained mosaic of sericite chlorite and quartz.

The rocks of sections 4 and 5 could be confused with those in the Chails. Tourmaline and plagioclase do not necessarily occur in the same slice. The plagioclase does not necessarily give rise to sericite on crushing, since even in crushed rocks full of secondary sericite, the detrital plagioclase may be fresh (21978).

Similar features are seen in the phyllites, but the ratio of matrix to detrital grains is greater. False cleavage occurs, oblique to the fine bands of phyllite and phyllitic quartzite (21971).

The finer-grained, mottled, green-purple beds are difficult to examine. A very fine and intimate association of quartz, chlorite and sericite is just discernible, the individual chlorite laths being up to 0·05 mm. in length (21974).

The limestones are generally crowded with detrital quartz and very frequently plagioclase, microcline, and tourmaline (21982). In most of the slices, there has been corrosion of quartz by carbonate (21983). The grains of quartz have lost their smooth edges, and show in growths of small prisms of carbonate. Apart from the detrital quartz, there is a finer-grained interpenetration of authigenic quartz and carbonate (21980).

## Blaini.

There are two typical rock-facies in the Blaini :—the boulder bed or tillite, and the limestone. These form the most unique and

striking rock association of the whole area. There is, however, no typical development of the Blaini, since no two exposures agree in character. The boulder bed may occur alone; or limestone may occur alone. There may be several boulder beds, with or without limestones. The boulder beds, and/or limestones, may lie on Simla slates, on Jaunsars, in beds of Jaunsar type, or in those of Infra-Krol type. This last manner of occurrence is particularly common in the Solan area. The slates of Infra-Krol type that are so intimately connected with the Blaini, should probably be mapped as Blaini. Since, however, the boulder beds and limestones often die out laterally along the strike, there has in many cases been embarrassment in distinguishing between Blaini and Infra-Krol slates that are lithologically identical, but, which, on account of this absence, are no longer separated in dip section. Consequently, those slates of Infra-Krol type that occur below the Blaini are mapped as Infra-Krol. Similarly, conglomerates of Jaunsar type associated with the Blaini are mapped as Jaunsar.

Boulder beds or tillites.

The tillites are described in plural, though it is uncertain in the present area to what extent repetition of boulder beds and limestones in dip sections is due to original sedimentary repetition, and to what extent to imbricate faulting. That there must have been locally more than one boulder bed is shown by the presence of water-rounded boulders of tillite itself in tillite (Plate 20, fig. 2).

The boulder beds are generally dark grey-brown in colour, and consist of angular, sub-angular and rounded boulders set in a fine-grained matrix. The matrix may be clayey or gritty. The quantity of boulders varies, they in some exposures being absent. The boulder-free matrix in such cases is often a greenish, hard quartzite full of closely packed polygonal joints, as at Lagasan and in the Damkri *nala*. The size of the boulders varies from three feet to that of very small pebbles. Their angularity is for the most part determined by the jointing and thin-bedding of the parent rocks from which they were eroded. There is gradation from tillite to conglomerate, containing rounded pebbles of vein-quartz. Good examples of this gradation may be seen in the *nala* which flows south from Kandon to join the Giri river. The boulder beds may be strongly sheared, in which case the matrix becomes cleaved, phyllitised and eventually schistose, while the pebbles become flattened out so as to be difficult to distinguish from the matrix. This is best seen on the Juint

Chandpur ridge. Scratches are sometimes found on the boulders, but it is impossible to be sure whether these are due to internal friction or to glacial action. Certain Jaunsar phyllites north of Shallai show the presence of grooves, which were at first taken to be due to internal friction, but which, on closer inspection under the lens, are found to be corrugations or minute cross-folds running perpendicular to the strike of the strain-slip cleavage.

The boulders and pebbles are of the following types:—dark slate, greenish quartzitic grit, pale quartzite, pepper sandstone, green siltstone or slate, banded slate, vein-quartz, occasional microcrystalline limestone weathering buff-coloured. Their provenance is undoubtedly the Simla slates and the Jaunsars. The provenance of the limestone fragments is uncertain. In one case the limestone appears to be of Blaini type (19194).

**Limestone.**

The limestone is generally pink and microcrystalline. It does not effervesce with acid or scratch with a knife. Its bedding is from half an inch to six inches and is generally contorted. Another type of limestone is one which is sandy and soft, weathering to thick dark orange-brown crusts. This is often distinctly ferruginous.

The limestone grades by addition of clay matter into calcareous shales and slates, which may be purple or pink in colour. Sometimes these are all that is seen in the Blaini, as at Barog Station, at the base of the Krol thrust.

Out of the great variety of sections seen in the Blaini rocks, the following three may be taken:—

(*a*) *In the Tons river, below Andra* (30° 36′ : 77° 44′)—

Infra-Krol slates with true cleavage.
Blaini boulder bed, 20 feet thick.
Jaunsar quartzites.

(*b*) *In the Kawal Khal, near height 3,241 feet* (30° 50′ : 77° 10′).

Infra-Krol banded clay-slate.

| | Feet. |
|---|---|
| Purple and pink, banded, slaty limestone | 50 |
| More massive, pink, lenticular limestone | 10 |
| Highly sheared boulder bed, with twisted knots of gritty clay-slate | 25 |
| Finely banded green and purple crinkled slates | 30 |
| Typical boulder bed | 25 |
| Sheared slates and slaty quartzites | 10 |
| Conglomerate with 'eggs' of vein-quartz | 15 |
| | 165 |

Banded and sheared bleaching slates, coloured on map as Infra Krol, but properly Blaini.

### (c) *Dhar spur, near hill 4,960 feet* (30° 58′ : 77° 02′ 30″).

Infra-Krol shales and slates.

| | | |
|---|---|---|
| Pink limestone . . . . . . . | 6 | Horizontal distance of section, about 4,000 feet; dips variable, but minimum thickness 2,000 feet. Most of this is due probably to thrust multiplication (see Plate 25, Section 1). |
| Boulder bed . . . . . . . | | |
| Slates and gritty slates. | | |
| Limestone . . . . . . . | 5 | |
| Boulder bed . . . . . . . | | |
| Papery slates. | | |
| Limestone . . . . . . . | 4 | |
| Boulder bed . . . . . . . | | |
| Slates and gritty slates. | | |
| Limestone . . . . . . . | 3 | |
| Boulder bed . . . . . . . | | |
| Slates and gritty slates. | | |
| Limestone (no boulder bed) . . . . | 2 | |
| Leafy slates with gritty slates. | | |
| Earthy limestone . . . . . . | 1 | |
| Red shales . . . . . . . | | |
| Pink limestone . . . . . . . | | |
| Boulder bed . . . . . . . | | |

Bleaching and papery slates, mapped as Infra-Krol. A small wedge of Subathus. The whole has been thrust over Subathus, by the Krol thrust.

## *Microscopical.*

The matrix of the boulder bed shows angular fragments of quartz, quite ungraded, set in a dirty fine-grained quartz-clay matrix, with secondary sericite in laths of 0·016 mm. (22001). When the boulder beds are more crushed the sericite becomes longer, 0·03 mm. (22002). Exceptionally the matrix is of calcite or dolomite (21999), as in the outcrops of Blaini near Masria.

Pebbles include :—

| | |
|---|---|
| Recrystallised mosaic quartzite (21999) . . | Probably Jutogh. |
| Sericite-quartzite (21999) . . . . . | Probably Jutogh. |
| Fine-grained arkosic sandstone with ? glauconite (21999) . . . . . . | Simla slates. |
| Sandstone containing many grains of phyllite and carbonaceous slate (21998, 19195) . | Simla slates. |
| Grit with isotropic clay paste matrix, similar to grits below Blaini at Gadhasar (19193) . | Blaini. |
| Fine-grained sandy limestone (19194) . . | Blaini. |

This list is not representative, since specimens for rock-sections were not taken from pebbles whose provenance was unquestionably Simla slate and Jaunsar. In particular this applies to the abundant boulders of dark slate so universally found in the Blaini.

The limestones do not call for comment. The typical hard siliceous limestone shows a very fine-grained mosaic of carbonate with interpenetrating quartz, and rare feldspar (19201). The impure sandy limestones show abundant quartz, with occasional oligoclase, detrital white mica, set in a matrix of carbonate (21997).

## Infra-Krol.

The Infra-Krols are made up of highly incompetent rocks which have been so folded and inter-faulted that no representative section and no reliable estimate of their thickness can be made out. Fresh rocks of the Infra-Krols in stream sections differ so markedly from the more commonly seen weathered rocks on hill-sides that it has sometimes been difficult to assure oneself of their original identity.

The Infra-Krols consist chiefly of dark shales and slates, closely interbedded with thin buff-weathering a quarter of an inch to four-inch bands of impure slaty quartzite. This banding is close enough to be called of *varve* type. Occasionally thicker beds of pepper quartzite are found. Towards the top of the Infra-Krols (that is, in sections seen below the Krol sandstone and limestones), black carbonaceous shales or slates occur without the thin bands of slaty quartzite. The overlying of paler Krol sandstones on black Infra-Krols is well seen on the spurs south of Krol Hill and north-west of Rajgarh Hill. From a distance the dark carbonaceous beds shine in a striking manner in the reflected light of an afternoon sun.

The banded facies of dark shale and paler impure quartzite weathers on hill-sides to a very characteristic association of thin, bulbous, sheeny, gritty clay-slate, often green in colour, and concentric ring-bleached slates. The latter are ramified with irregular joints, now marked out by harder ridges as a result of liberation of iron and its precipitation as ferric hydroxide cement. On account of strong small-scale folding and recent cementation, these two rock types usually occur together in complete chaos. The commonness of iron in the Infra-Krols is seen in the universal seepages of ferric hydroxide, and white incrustations of ferric sulphate and chloride, which cover the surfaces of these rocks. The parent mineral must have been pyrites.

The Infra-Krols show great variation in the extent of metamorphism. In the Solan neighbourhood shales predominate, though at the closing end of the Krol syncline, in the lower Blaini river, the shales become true slates, with cleavage dip to the north-east. The intervening harder bands do not cleave. East of Dadahu the Infra-Krols are universally cleaved, while northwards, north of Soat and on Juin and Chandpur Hills, some of the beds turn into pearly phyllites and even become schistose. In these places they are ramified by veins of quartz. Their identification with the Infra-Krols is told by their occurrence between the Blaini and Lower Krol limestones,

which also show a concomitant increase in metamorphism, and is supported by the presence of ring-bleached slates of more normal Infra-Krol type. East of Dadahu cleavage varies in dip from 35° to 70°, and in dip direction from N. N. W. to N. N. E. The minimum thickness of the Infra-Krol rocks is about 500 feet, but no reliable estimate is possible.

*Microscopical.*

The cleaved slates consist of a poikiloblastic mixture of sericite and quartz with sericite up to 0·035 mm. in length. Pyrites is abundant (22005). The associated slaty quartzites, or gritty clay-slates, are frequently calcareous and show a reformed mass of quartz, carbonate, sericite, pyrites. Some of these tougher bands resemble the sandy limestone or calcareous sandstone facies of the Blaini (22004). Increase in alteration is told by the greater size of the sericite laths. Slice 22006 is a reformed mixture of chlorite, sericite and quartz, with considerable quantities of carbonate and pyrites. The chlorite and sericite may occur together in a single crystal in alternate layers parallel to the basal plane. In all these rocks, there is a large quantity of carbonaceous dirt.

## Krol Sandstone.

In the Solon neighbourhood, the Krol sandstone is generally seen as a soft crumbling sandstone, without good bedding and stained an orange colour with iron. Excellent exposures are found along the Kalka-Simla motor road, at the foot of Pachmunda Hill and at Salogra. North of Krol Hill, near Kandaghat, and in the *nala* which flows from Solon to join the Giri river, the sandstone is a hard quartzite in which bedding is well displayed. A conspicuous feature is the presence of bands rich in disc-like fragments of black shale, seldom over 2 mm. thick but up to 5 cm. long. These shale fragments readily bleach, and are almost certainly derived from penecontemporaneous erosion of the underlying Infra-Krols. Towards the south-east the sandstone ceases to be a single horizon, but splits up and becomes strongly interbedded with carbonaceous shale. Such interbanding may be seen in the Kawal Khal and at Ajga. Still further to the south-east, the intervening shale bands tend to disappear and, besides the quartzites with shale discs, there are coarser lenticular pebbly beds. The sandstone is 350 feet thick on the south face of Krol

Hill above Baran, 50 feet in the south-east corner of sheet 53 F/1, two feet in the Giri river at Dadahu, and dies out on the western side of hill 3,619 feet.

In the tightly squeezed Krol syncline in the Kawal Khal, the sandstone becomes a horny quartzite, strongly veined with quartz. At Kadhar, below a local thrust, it has been highly polished by friction and has been broken down (22010).

Mr. Wadia[1] has suggested that some of the Krol sandstone may be a metasomatised limestone. The microscopical evidence is against this supposition, since it is difficult to see how any replacement of lime by silica would result in such a striking grain structure as is shown by these sandstones. Had there been replacement, one would have expected an irregular mosaic of quartz and chalcedony. The only mosaic that has been observed is that in the crushed rock from Kadhar, where there is no question as to its mode of origin. The crumbling variety of the sandstone may probably be explained by de-silicification, and loss of the silica cement.

## *Microscopical.*

The most striking feature of the Krol sandstone in the neighbourhood of Solon is the degree of rounding of the grains. In very fine varieties, such as 19188, in which the maximum grain size is 0·15 mm., the grains are all angular. The remainder of the rock sections show excellent rounding in grains of 0·30 and 0·25 mm. in diameter. In two slices (19183, 19185), the rounding is well displayed in grains of 0·20 and 0·17 mm. diameter. There is generally a strong silica cement (19186, 19184).

In the sheared sandstone from Kadhar (22010) are seen veins of crushed rock which are now a recrystallised mosaic of quartz and from which the clastic structure has been quite lost. There are intense strain shadows, and an increase in birefringence of the chlorite envelopes to the grains. This crushing is local, since in the same slice may be seen less crushed grains, 0·20 mm. in diameter, in which the rounding has not been obliterated.

The rounding of the grains is almost certainly due to wind action, since 0·30 mm. appears to be the minimum possible diameter for rounding caused by attrition in water.[2]

[1] *Rec. Geol. Surv. Ind.*, LXV, p. 128, (1931).

[2] Bailey, *Geol. Mag.*, p. 105, (1924). Twenhofel, 'Treatise on Sedimentation', pp. 165-170, (1926), cites experiments by Galloway in which the lower effective limit of abrasion in water is considerably less than 0·30 mm., particularly for soft minerals. However, the percentage of well-rounded grains of hard quartz in the Krol sandstones is over 50, and the deduction given above is probably valid. The rounding was due to wind, but the sandstones were water-deposited.

## Krol Limestones.

In this division of the Krol series is a great variety of limestones and shales. In the Solan area, Oldham divided the Krol limestones into three sub-stages :—

Upper Krol limestone,
Red Shales,
Lower Krol limestone.

Between longitudes 77° and 77° 25′, it has been found possible to subdivide the Upper Krol limestone into three sub-stages, so that in all five sub-stages have been mapped in order the better to bring out the structure of the belt. For the most part, differentiation has been relatively easy. In places, however, on account of a basic similarity shown by some of the limestones in the three upper sub-stages, and owing to the intense folding which the eye can see to have taken place, aside from what is evinced by the mapping itself, differentiation has been more uncertain. This applies chiefly to squares A 1 and B 1 in sheet 53 F/6. East of 77° 25′, the original three divisions made by Oldham in the Solon area have been adhered to, although locally, especially near Mishwa, it would have been possible to delineate all five. Here, however, no useful purpose would have been served by subdividing the Upper Krol limestone, since the overlying Tal beds have prevented the Krols folding individually. Tals, Krol limestones, Infra-Krols and Blaini fold as a single unit. The combined thickness of the Krol limestones varies from about 1,800 feet to nearly 4,000 feet.

### *Krol A (Lower Krol limestone).*

In the area round Solon, this stage is made up of limestones and shales, in beds from one to four inches thick. Weathered surfaces show subdued grey-green tints. Fresh fractures are bluer. The limestones are seldom crystalline. In composition these beds show rapid alternations of shaly limestone and calcareous shale or slate; either in parallel beds (Plate 21, fig. 1), or as discontinuous, in-weathering, lenticular pillows of limestone surrounded by calcareous shale (some are seen in Plate 22). Near Solon, at the top of the stage, is a more massive 20-50-foot limestone, which is frequently dolomitised.

Small-scale current-bedding is often seen (39·800), and in a few places, ripple-marks. Near Kotla and Dadhag, the ripples have been

accentuated by subsequent compression.[1] Discontinuous structures, once formed, appear to have acted as avenues of relief to later stress. The strike of these ripples is 120°–300°.

Fracture cleavage is universal. The calcareous shales, thus cleaved, may be seen lying about the hill-sides as pencils and needles. Towards the east, the shale facies begins to show true oblique cleavage. Between Dadahu and the Tons river, the Krol A stage is recognised by the presence of banded grey and green slates (44·91), while northwards, near Milla and Mangal, the slates become puckered, veined with quartz, and almost phyllitic. The puckering at Milla is parallel to 130°–310°. In the east, distortion of the beds and lenticles of purer limestone becomes marked (Fig. 7 and Plate 22).

Black chert is common as thin bands, or in pillows up to nine inches long and three in height. At latitude 30° 33′ 22″ : longitude 77° 44′ 51″, gypsum, with subordinate anhydrite, was found in a bed, 18 inches thick and 20 yards long, which appears to be an original deposit in the Lower Krol limestone.

In the Solon area, the apparent variation in thickness of these limestones is from 100 feet in parts of the south-west flank of the Belt, to some 2,300 feet, one mile south-east of 6,066 feet hill. The former thickness is due partly to reduction by thrust elimination, and the latter thickness to thrust multiplication. The real thickness probably varies from 300 feet on Pachmunda Hill to 700 feet on hill 6,066 feet. Within the area included by the maps, there seems to be no great variation, but further south-east, by Mussoorie and in Garhwal, these beds appear to become much thinner.

### *Krol B (red shales).*

This sub-stage is characterised by soft, thinly laminated, purple-red shales, with blotches and intercalations of green shale. Thin dolomitic and cherty limestones are common. Ripple-marks are sometimes seen. Near the top of this division are parallel-bedded, shaly limestones similar to those in the Lower Krol limestone. The shales of this sub-stage are very incompetent; bedding is seldom preserved and their thickness is variable, owing to internal packing in the cores of folds and attenuation along the limbs. Slaty cleavage is never developed. Adjustment to stress takes place along countless

[1] Registered negatives (9× 12 cm.) Nos. 298, 299. Rock specimen No. 43·748.

irregular slip surfaces, in the greener shales, with formation of chloritic minerals. The maximum undisturbed thickness of these shales is about 300 feet.

### *Krol C.*

This is the most conspicuous limestone on the hills round Solon, occurring in a single cliff from 150 to 300 feet in height. It is a massive, dark-blue, crystalline limestone, which usually stinks on fracture, and weathers to black 'chopping-board' surfaces. Dolomitisation is often seen.

### *Krol D (chert, limestone and shale sub-stage).*

In this sub-stage are alternations of cherty limestones and shales, with shale usually in excess of limestone. The limestones are either pale or dark and stinking, in beds from ten to 30 feet thick. The chert is pale and occurs as thin wisps and in continuous bands up to two inches thick. The shales are of black, red, green and orange colours, the darker varieties often bleaching in a manner similar to those of the Infra Krols. Rare conglomerates occur, with pebbles of vein-quartz and of chert. Soft white sandstones are often found. Some of the limestones are penecontemporaneous breccias. The rocks of this sub-stage may be recognised on the terraced south face of Krol Hill, above the cliffs of the Krol C limestone, but their most characteristic development is between Bhaunrari and Mangarh, where the limestones readily twist into small scale overfolds in the great excess of shale (Plate 19). Gypsum was found as pockets replacing limestone near Bhaunrari. The minimum thickness of this sub-stage south-east of Narag is about 600 feet.

### *Krol E.*

The rocks of this division afford rugged scenery, since they are seldom seen below 4,000 feet. Bedding is well developed, from one to five feet. The main rock type is a banded grey and pale cream-white microcrystalline limestone. Freshly fractured surfaces of the paler varieties are white and porcellanous. Thin crinkled veins of calcite are common in the form of 'sutures', which stand out slightly on a weathered surface. These limestones pass by increase of grain-quartz first to pale sandy limestones, in which the quartz grains stick out as small millet seeds, and finally to pale calcareous sand-

stones. More rare are saccharoidal crystalline limestones and cream-white limestones showing tubular and ellipsoidal growths of calcite, radial to cores of calcareous mud. These growths are deceptively like corals. Red, orange and black shales are present, but are subordinate in amount to the limestones. The minimum thickness of this sub-stage is about 500 feet. Between Mishwa and Dugana, the combined thickness of the C, D and E sub-stages is of the order of 3,000 feet.

### *Microscopical.*

The Krol A limestones are very fine-grained and show clusters of carbonate in an almost isotropic matrix (22012) with quartz, sericite and pyrites (22013). In the more horny and siliceous varieties, carbonate is rare and sericite and quartz occur in a fine-grained to cryptocrystalline pulp (22014).

The limestones of Krol C and D are purer, showing simple mosaics. Stress results in idioblasts of coarsely crystalline calcite, from the size of a pin-head to nodules 2·5 cm. long, embedded in finer limestone (22018, 22019). Some of the cherty limestones show carbonate crystals embedded in cryptocrystalline silica.

The Krol E limestones are more interesting. Those that were sliced were chiefly sandy limestones. The sand grains are both angular and rounded, being found up to 2 mm. in diameter. Pellets of calcareous mud are common (22020). The grains of quartz have been corroded and replaced by carbonate which occurs as ingrowths obliterating former edges (22024). In 22027, microcline appears similarly to have been replaced. In the saccarhoidal limestones, quartz and calcite have crystallised out side by side, with the quartz showing good hexagonal sections (22025). Replacement of quartz by calcite should result in an increase in volume, since the molecular volumes of the two are respectively 22·67 and 36·85. No sign of strain due to expansion is seen, which is probably to be explained by the capacity for flow, rather than fracture, of limestone. Tourmaline is a common detrital mineral, particularly in the limestones round Mishwa (22027).

## Tals.

These beds occur in two synclinal basins completely surrounded by Krols. When first encountered in 1930, the upper stage of the Tals was regarded as Jaunsar and the lower stage as Infra-Krol. Later they were considered to be a completely new series, lying normally above the Krols, and to be equivalent to the Tal beds described by Middlemiss in Garhwal.[1] This conclusion has been confirmed, with as much certainty as is possible in correlating between rocks of isolated basins.

[1] *Rec. Geol. Surv. Ind.*, XX, p. 33, (1887).

Medlicott[1] noticed beds belonging to the upper stage of these Tals on what was then called 'Kerloe' peak. This peak is in approximately the position of Giltu ka Tibba, hill 7,005 feet (30° 40′ : 77° 29′). He was mistaken in correlating them with the Krols, and in underestimating their thickness.

The scenic changes from the rugged cream-white limestones of the Krol E stage, to the soft dark shales and graywackes of the Lower Tals, and from these to the pale cliff-forming Upper Tal quartzites, are very striking.

*Sequence of Tal beds.*

| | |
|---|---|
| Upper Tals | Dark limestones and calcareous sandstones; quartzites; shales.<br>Massive arkosic sandstones or quartzites; pebble beds; shales.<br>Alternating quartzites, often pebbly, with shale or slate. |
| Lower Tals | Micaceous shales or slates with a few quartzites.<br>Thick series of carbonaceous shales and dark graywackes, in massive beds marked out by finer banding and current-bedding. These pass laterally to tough slates and phyllites.<br>Black chert beds and carbonaceous shales or slates. |

The beds of the Lower Tals, particularly when converted into slates, are often very similar to those in the Infra-Krols. When uncleaved, they are usually to be distinguished by their more massive bedding, and by the abundance of dark graywacke, both features being absent from the Infra-Krols. The carbonaceous shales readily bleach, but generally as a uniformly weathering crust, and not in rings as in the case of the Infra-Krols. Many of the graywackes are strongly calcareous. Ripple-marks are sometimes seen. In the western basin, the Lower Tals vary from about 1,800 feet in the west to 3,500 feet in the east. In the eastern basin, they probably do not exceed 2,000 feet.

Quartzites form the most characteristic member of the Upper Tals (Plate 18). They are generally arkosic, and vary in colour from white to pale green. Occasionally there are found purple sandstones (7,216 feet peak). Current-bedding is universal and ripple-marks are common. Many of the sandstones are pebbly, containing pebbles of vein-quartz, green slate and pink feldspar, which is abundant and sometimes up to 10 mm. long. Pebbles of feldspar are not seen so often in the eastern of the two basins, though arkosic sandstones are common there.

[1] *Mem. Geol. Surv. Ind.*, III, p. 45, (1864).

Interbedded with the Upper Tal quartzites are purple, red, and green micaceous shales. Some of these are striking in their irregular vermicular tubes and nodules of pale sandstone. These shales were probably sub-aerially exposed, the turned-up edges of sun-cracked mud becoming filled in with later washings of sand. Near Gubsar, where the Tals have been tilted vertically in proximity to the Guma thrust, shales have been converted to puckered phyllites. Clay-slates are common in the northern part of the western basin.

The limestones are always dark, sandy and current-bedded. No fossils have been found. Soft sandy limestone may be seen to lie on hard, highly jointed quartzite (Plate 23).

The thickness of the Upper Tals, in the eastern basin, when not reduced by thrust faulting, is about 2,000 feet. In the western basin, it is probably, greater since the sandy limestones at the top are there preserved.

Allusion has been made to the similarity between the Lower Tals and the Infra-Krols, and between the Upper Tals and the Jaunsars. Differentiation between the Infra-Krols and Lower Tals is chiefly megascopic. The differences between the quartzites of the Jaunsars and the Upper Tals are as follows :—

| | Jaunsar quartzites. | Upper Tal quartzites. |
|---|---|---|
| Tourmaline . . . | Rich . . . . | Not nearly so rich. |
| Plagioclase . . . | Rich . . . . | Poor. |
| Microcline . . . | Poor, except in Nagthat stage. | Rich. |
| Strain features . . | Strong, and marked by frittering along grain edges, ending with schistose structures. | Sometimes strong, and marked by new quartz mosaics. Quartz-schist never seen. |
| Megascopic appearance . | Generally dirty quartzites which may show intense ramification by veins of quartz. Frequently schistose. | Generally whiter, less horny and not so markedly permeated by quartz. |

The shales and clay-slates of the Upper Tals lack the phyllitic and tough slaty condition usual to the Jaunsars. Phyllites in the Tals are rare. In manner of origin, it is probable that some of the Jaunsars and Upper Tals were formed under almost identical delto-continental conditions.

## *Microscopical.*

Carbonate is present in all the massive graywackes. No ferromagnesian minerals, like augite or hornblende, have been found, such as are properly required

by the definition of these rocks, but the abundance of chlorite suggests formation from minerals derived from basic rocks. Biotite is common, but less so than white mica. The main part of the rocks consist of reconstructed quartz-chlorite-carbonate and quartz-sericite-carbonate. Chlorite occurs as laths, in hexagonal plates and in bundles (22034). Plagioclase may be common (22033). Some of the graywackes may be tuffs.

The grain-size of the Tal quartzites averages 0·50 mm. Most of the sections show abundant microcline (22039, 22041). Plagioclase is not common. Tourmaline is a frequent accessary (22038). Chlorite may occur as envelopes to the grains (22035). Clastic structures may be partly or almost wholly obliterated on account of recrystallisation, first as small-scale mosaics along the edges of grains, and finally, after passing through a stage of heavy strain shadows (22041), to a coarser interpenetration mosaic throughout the grain (22038). Bundles of sericite are formed.

In the arkose from the Gubsar locality, the clastic structure is still clearly discernible, particularly in ordinary light, but the strain shadows are severe and there has been incipient recrystallisation (22032). The associated puckered phyllite (22031) shows cleavage oblique to the bedding, and rotation of quartz grains in a gritty band. Abundant new mica has formed parallel to the cleavage, coalescing in directions perpendicular thereto.

## Tertiaries.

It is not necessary to go into detail about the Tertiary rocks.

Subathus.

The Subathus consist of olive-green and purple, oily-looking shales, ramified with minute irregular joints, and by planes of movement which are often filled in by calcite. There are also green and white sandstones, iron-stained quartzites, and rare ripple-marked shaly sandstones. Shelly limestones and unfossiliferous sheared limestones, full of veins of calcite, are common. Well-preserved fossils are rare, the shelly limestones being made up mostly of broken oysters. Nummulites are seldom seen. Two characteristic facies, of limited distribution, are a ferruginous pisolitic laterite and carbonaceous bed, one specimen of which contains over 60 per cent. of carbon. Very occasionally, conglomerates made up of fragments of pale microcrystalline limestone, set in calcareous sandy mud, are found. The provenance of the limestone fragments is not known. They do not match any seen in the Krol series, nor those in the Subathu rocks themselves.

Near Kalka, along the Kawal Khal, and east of Dadahu, occurs an abnormal metamorphic facies of the Subathus. The purple and green shales become phyllitised and veined with quartz, while the carbonaceous shales are converted to dirty bleaching slates, exactly

similar to those in the Infra-Krols. Greenstones are locally common east of Dadahu. A band of massive limestone, thicker than is usually found in the Subathus, is strongly developed near Sataun.

In the Kasauli neighbourhood, Col. Christophers has shown me a well-defined, white, quartzitic sandstone which intervenes between the Dagshais and the Subathus, and is a useful mapping horizon. The Dagshais proper consist of alternations of purple, cindery, sandy shales and purple or green sandstones, in beds up to 15 feet thick. The effect of these alternations on the scenery between Dagshai and Subathu is very striking.

**Dagshais.**

Current-bedding and ripple-marks are common. Conglomerates occur, containing the same type of limestone fragments as are found in the Subathu conglomerates, and also red shale derived from contemporaneous erosion. Between Dagshai and Subathu, these beds are 2,000 feet thick.

The Kasauli beds differ from the Dagshais in their general lack of purple colour, and in the predominance of sandstone over shale. The shales are less cindery, and greener. They may be either soft, or hardened to clay-slate. Some contain fragments of palm leaves. The sandstones are massive and generally hard.

**Kasaulis.**

The Nahans show the same regular alternation of sandstone and shale. The sandstones are massive, soft, green-brown in colour, rudely jointed, and coarsely current-bedded. The clays are chocolate and green in colour, and usually concretionary. Both sandstones and clays are streaked with purple.

**Nahans.**

## *Microscopical.*

The Subathu sandstones are often calcareous, and owe their greenish colour to chlorite. Glauconite is fairly common (22042). The phyllitised Subathu shales show new chlorite associated with veinlets of quartz (22044).

The Dagshai sandstones are seldom calcareous. They contain fragments of phyllite, carbonaceous slate (Infra Krol or Subathu ?), rare limestone and Subathu-like sandstones. Minerals include tourmaline, garnet, plagioclase, kyanite, zircon and derived glauconite. They give the appearance of initial loose packing of phyllite and slate fragments with sand, and subsequent compression, with splaying-out of phyllite to yield new matrix (21951, 22046).

Garnet is common in the Kasauli sandstones (19225, 21941).

The Nahan beds (including Pilgrim's division of Sutlej beds, north-west of Subathu) are of interest in the frequent presence of fragments of volcanic rock (21946, 21945, 21948, 21947). These appear to be glassy andesites and basalts, the

latter largely chloritised. They differ from the greenstones found intrusive in the Subathus and Nahans east of Dadahu. Garnet, tourmaline, plagioclase, microcline, glauconite, and fragments of phyllite, carbonaceous, slate and limestone are common. Carbonate becomes an important constituent, in many of the Sutlej sandstones being over 10 per cent. of the rock.

## Dolerites and Allied Rocks.

Basic hypabyssal rocks have been found in the following formations :—Jaunsars, Infra-Krol, the A, B, D divisions of the Krol limestones, the Subathus and the Nahans.

The dolerites in the pre-Tertiary rocks are occasionally found fresh and not sheared, but more usually are sheared and may even be converted to chlorite-schists. Most of the specimens are green with patches of white representing saussuritised feldspars.

The basic rocks in the Tertiaries are now greenstones. Shearing, and perhaps hydrothermal action, has been intense. No schists have been produced; instead there are innumerable irregular slip surfaces, so closely packed that it is impossible to obtain a good hand-specimen.

### *Microscopical.*

Under the microscope the pre-Tertiary dolerites (22040-22057) are seen to contain :—magnetite or pyrites. apatite, augite, biotite, plagioclase feldspar, quartz. and alteration products.

Plagioclase is always in excess of pyroxene. Biotite is a common constituent. A graphic intergrowth of the later crystallised plagioclase with quartz is generally present.

The pyroxene is augite. Under stress it changes variously to antigorite, chrysotile, uralite and chlorite.

The biotite is usually associated with magnetite and chlorite.

The plagioclase is always zoned and varies in composition from oligoclase to andesine. It is generally badly saussuritised.

Quartz is common, both in individual crystals and in graphic intergrowth with plagioclase.

Carbonate is frequently found, resulting from the liberation of calcium on the break-down of augite and plagioclase.

These rocks range from quartz-oligoclase-dolerites to quartz-andesine-dolerites. They may be called comprehensively *leucophyres.*

The dolerites in the Tertiaries (22058, 22059, 22060) may belong to the same suite as those just described, though they show a greater quantity of feldspar and

quartz. The intergrowth of these two minerals is more involved, approaching micropegmatite. The augite is very seldom preserved, being represented by chlorite, uralite, magnetite, pyrites and calcite. The feldspar laths are generally completely saussuritised. Carbonate is abundant. The relative freedom of the quartz-plagioclase intergrowths from saussuritisation suggests that some of this may be of secondary origin, a hydrothermal effect more or less simultaneous with the movements which resulted in the break-down of the original dolerites. These rocks may also be called leucophyres.

## V. DIFFICULTIES OF CLASSIFICATION.

A certain experience of the rocks of the Krol Belt has impressed upon one the fact of striking similarities between rocks of different series. The series as given in the table of formations, and as shown on the map, represent the outcome of weighing-out evidence of similarity and dissimilarity, and of studying sections in localities where the rocks have not been excessively disturbed. Once established, either in the text or on the map, the dissimilarities which led to the ultimate differentiation of the rocks tend, perhaps, to obscure the similarities which also exist. Given more or less complete sections, or given continuity along the strike, there is generally little difficulty in adjudicating the importance of similarity or dissimilarity, even when characteristic rock groups are missing, since the position of the rocks with reference to other known stages, about which there is no question as to which series they belong, by itself yields information. In many places, however, thrusting and folding have been so severe that single stages occur in abnormal positions, and die out without anywhere showing, in their small outcrops, characteristic rock facies of diagnostic value. In such circumstances, neither lithology nor position can assist in determining to which group they belong, and their assignation may be extremely difficult. As examples may be mentioned :—

(1) The outcrops along the Giri river from Tikari to the confluence with the Jagar ka Khala, which are mapped as Infra-Krol.
(2) The outcrops, 14 miles in length, from Chiyan to beyond Sataun, mapped as Infra-Krol.
(3) The outcrops round Rajana, mapped as Lower Tal.
(4) The outcrops between heights 2,820 and 2,795 feet on the Giri river, where an arbitrary line has been drawn between the Simla slates and the Jaunsars,

### *Characteristic facies of diagnostic value.*

*Simla slates.*—Chhaosa slates ; Domehr slates ; striking at Domehr, but untypical at Kandaghat.

*Jaunsars.*—Purple conglomerates with ' eggs ' of vein-quartz ; very inconstant. Crinkled slate-blue phyllite, strongly interbanded with thin phyllitic quartzite. Massive, blue, crystalline, sandy limestone (Bansa limestone).

*Blaini.*—In its normal position between Simla slates or Jaunsars, and Infra-Krol, is very striking ; but see Mandhali question, page 419.

*Infra-Krol.*—No single unique characteristic.

*Krol limestone.*—*Krol D* :—some cherty limestones ; of diagnostic value only in differentiating between the various Krol limestones ;

*Krol E* :—cream-white porcellanous limestones ;

The sub-stages do not often occur singly and completely isolated in foreign rocks. Combination of characters and relative position is of great value.

*Tals.*—Nature of bedding in Lower Tals and microscopic characters (microcline) in Upper Tals.

*Subathus.*—Olive-green and purple, oily-looking shales, with cuboidal jointing.

### *Lithological characters common to more than one series.*

(1) Black, apparently carbonaceous, shales or slates, which readily bleach, and often contain pyrites :—

Simla slates, Mandhalis, Jaunsars, Blaini, Infra-Krol, Krol sandstone, Krol D, Subathus.

(2) Banded, black and grey, ' varved ' slates and gritty clay-slate :—

Jaunsars, Blaini, Infra-Krol.

(3) Purple phyllites :—

Mandhalis, Nagthat stage, Subathu rocks locally sub-phyllitic.

(4) Red shales :—

Jaunsars, Blaini, Krol B (Tertiary red shales are more distinct).

(5) Conglomerates and pebble beds :—

Simla slates, Mandhalis, Jaunsars, Blaini, Krol D, Tals, Subathus.

(6) Boulder beds :—

Mandhalis, Jaunsars, Blaini.

(7) Arkoses :—

Jaunsars, Tals.

(8) White sandstones or quartzites :—

Simla slates, Mandhalis, Jaunsars, Blaini, Infra Krol. Krol sandstone, Krol D, Krol E, Subathus.

(9) (*a*) Lenticular limestones in calcareous shale or slate :—

(*b*) Thin-bedded, blue, microcrystalline limestones :—

Mandhalis, Krol A.

(10) Sandy limestones :—

Mandhalis, Jaunsars, Krol E, Tals.

(11) Shelly limestones :—

Tals, Subathus.

*Sedimentation characters common to more than one series.*

(1) Ripple-marks :—

Simla slates, Jaunsars, Krol A, B, D, Tals, Subathus, Dagshais.

(2) Current-bedding :—

In the sandstones and quartzites of all the series.

(3) Mud-cracks :—

Jaunsars, Tals.

It is evident that most of the series were deposited under shallow water, epicontinental, conditions. The Jaunsars and the Upper Tals were probably continental formations, deposited in piedmont and fluvial environments.

## VI. REPETITION, CURRENT-BEDDING AND INVERSION.

It has been seen that the resemblance between facies members in what have ultimately been regarded as different rock series is often striking. In the field it has led to uncertainty in mapping, since similarity might be due to two causes :—

(1) Repetition in the course of time of similar sedimentary conditions; the existence, therefore, of distinct sedimentary series.

(2) Repetition of a single series by tectonic movements—

(*a*) by thrusting;

(*b*) by overfolding, with inversion.

When the beds which are now regarded as Upper and Lower Tals were first encountered in the Nigali syncline, I took them to be respectively Jaunsars and Infra-Krols. On this interpretation, supposed Jaunsars overlay supposed Infra-Krols and these, in turn, rested on Krol limestones. Close by, known Jaunsars had been found normally to underlie known Infra-Krols (with the Blaini intervening). The thought, in fact the hope, presented itself that a great overfold had been found, causing the repetition, in inverted order, of Jaunsars and Infra-Krols above the Krol limestones.

| *Correct succession.* | *Possible succession.* |
|---|---|
| Upper Tals | Inverted Jaunsars. |
| Lower Tals | Inverted Infra-Krols. |
| Krol limestones | Krol limestones. |
| Infra-Krols | Infra-Krols. |
| Blaini | Blaini. |
| Jaunsars | Jaunsars. |

To decide if this were so, the current-bedding surfaces of the quartzites which are now regarded as Upper Tals, and of those in the true Jaunsars, were examined.

Current-bedding.

The principle involved is that in undisturbed areas, the current-bedding surfaces face concavely upwards. If cases are found in which the current-bedding surfaces face convexly upwards, it may be assumed that the beds in question are inverted.

Cloos[1] appears to have been the first to use this method, while it has been employed with considerable success by Prof. Bailey and others in Scotland.[2]

Cases are found in which the current-bedding occurs as plane-surfaces, oblique at a constant angle to the true bedding. Other cases are seen in which the curves of current-bedding are inflected, and asymptotic both towards the top and bottom of the bed of sandstone. These are rare, and are of no use in demonstrating inversion. Inflected forms have occasionally been seen in the Siwalik sandstones, and in the sandy Bansa limestone of the Jaunsars, but they are very uncommon in comparison with the normal type of current-bedding surfaces which are truncated above, and asymptotic below.

Prof. Boswell has been kind enough to write to me on this subject. He states that in experiments which he and Prof. Wilton have carried out on the deposition of sand of average diameter 1-100th of an inch (0·25 mm.) in glass-sided troughs, the following results were obtained :—

(1) With moderate velocity, up to 1·2 feet per second, ripples of wave-length of about three inches were produced, and current-bedding occurred of inflected form, asymptotic at the top and base.

(2) With increased velocity, up to 1·5 feet per second, the tops of the ripples were eroded to a plane-surface, abruptly truncating the bedding.

(3) With still higher velocities, larger 'whale-back' ripples were formed, of wave-length of ten or more inches, on the lee side of which the bedding, although asymptotic at the top of the mounds, abutted abruptly on to the floor of the underlying material.

The commonest type found in sedimentary rocks corresponds to that in section (2); that of section (1) has been seen, but is not

[1] *Zeitschr. f. prakt. Geol.*, p. 340, (1914).
[2] *Geol. Mag.*, p. 68-92, (1930).

common; that of section (3) I have not seen. In the Kaimur rocks of the Vindhyan plateau, current-bedding is universal, and is always of type (2). Contradictory cases, in which the current-bedding is convex upwards, do occur in sedimentary rocks, and are ascribed by Prof. Boswell to exceptionally high velocities of transport.

It is agreed that, given a large enough number of cases, and neglecting those that are ambiguous, it is possible to use the disposition of current-bedding as a means of determining whether inversion has taken place.

When applied to the Tal quartzites of the Nigali syncline (Plate 23) and to the Jaunsars of the cliffs overlooking the Tons river, it was found that both sets of quartzites were in a normal, uninverted condition. It was impossible, therefore, to suppose that the Upper and Lower Tals were inverted Jaunsars and Infra-Krols in the middle limb of a recumbent fold. The alternative explanations were either that thrusts had brought uninverted Jaunsars and Infra-Krols on to Krols, or that the rocks in question belonged to a later series than the Krols, in normal order above them. A wider experience of the rocks above the Krols showed that the two divisions graded into each other, by the increase upwards in number of quartzitic bands. The change in lithology is so gradual that it was impossible to map the boundary between the two divisions within a range smaller than 200 feet.

Further, no sign of Blaini beds has ever been seen between the two divisions. The Blaini is, it is true, sometimes eliminated from the normal Jaunsar-Blaini-Infra-Krol succession, but never extensively so. If thrusts had brought Infra-Krols over Krol limestones, and Jaunsars over both series, it would be very surprising that the Blaini, which normally intervenes, should never be seen incorporated in the thrust masses.

These facts, together with the lithological differences enumerated on page 391, seem sufficient to warrant the belief that the beds overlying the Krol limestones belong to a later series. The occurrence in Garhwal of Tal quartzites overlying massive limestones, similar to the Upper Krol limestones, is enough to clinch the matter, because in Garhwal there is not the same difficulty of the existence of an underlying, highly quartzitic series with which the Tal series could be confused.

The disposition of current-bedding has further shown that the Simla slates in the Gambhar river to the south-west of Simla, the

Jaunsars north of the Giri river (east of Dadahu), and the Jaunsars north of Kando, are in a normal, uninverted order.

Inversions in which strata have been folded through 120°, are fairly common, especially along the north face of Kamli Dhar. These have come to light as a result of mapping, since the stages concerned do not contain current-bedded sandstones. Further, minor flat folds are often seen from a distance in the limestone bands of the Krol D stage, but these occur on a small scale in rocks, which, taken as a unit, are in normal order (Plate 19).

As applied to the Krol Belt, the examination of current-bedding has been of most use in deciding whether or not the great outcrops of quartzites of the Tal, Jaunsar and Simla series have been completely inverted in large-scale recumbent folds.

The general structure of the Krol Belt is clearly one of uninverted, or only slightly overturned, sequences, which have been brought forward by thrusts, and not of recumbent folds.

## VII. ORIGINAL SPATIAL RELATIONSHIPS BETWEEN DIFFERENT SERIES.

### Simla Slates, Jaunsars, Blaini ( ? Mandhali).

The sequence given by Pilgrim and West was in descending order :—Blaini : Simla slates : Jaunsars.

This was based on two main considerations :—

(1) The Blaini was found most usually to overlie Simla slates.

(2) The Jaunsars appeared to be more metamorphosed than the Simla slates and were therefore regarded as older than them.[1]

Between the Gambhar and Giri rivers, Jaunsars had been found to overlie Simla slates, usually with supposed Blaini intervening. The explanation given was that Jaunsars had been thrust into an abnormal position upon the Simla slates with their capping of Blaini. Any Infra-Krol slates and Krol limestones that might originally have overlain this Blaini, were thought to have been planed off from the Blaini and pushed south over the present belt of Krol rocks.

Subsequently it has been found that over wide stretches of the Krol Belt, particularly in the east, Infra-Krol and Blaini lay directly

[1] Pilgrim and West, *op. cit.*, p. 21.

upon Jaunsars. There was also evidence that the Jaunsars which overlay the Simla slates of 6,474 feet hill and Kandaghat, without the intervening boulder bed and limestone, might in reality be in a normal stratigraphical order upon them.[1] It was therefore suggested that the correct sequence might be Blaini : Jaunsars : Simla slates.

The greater general degree of metamorphism shown by the Jaunsars may be regarded as an accident of their lithological composition and of their position with reference to zones of greater stress.

This question is more complicated than was supposed in 1928. I had tended to ignore the usual occurrence of rocks resembling the Blaini between the Jaunsars and the Simla slates.

In places where I had worked in 1928, the intervening supposed Blaini was absent. There was an apparent lithological gradation from Simla slates upwards into Jaunsars, as may be seen on the Kandaghat-Chail motor road near Senj, and along the Subathu-Kathlighat mule-track between distances of four and 4½ miles from Kathlighat. Purple slates and quartzites increase in importance in the Simla slates, until they are finally succeeded by more massive Jaunsar quartzites with associated green and purple beds.

At the opposite, eastern, end of the Krol Belt, the Mandhali rocks, with boulder beds, pink limestones, and a complex association of conglomerates, quartzites, purple phyllites, bleaching slates and limestones, have recently been found to underlie Jaunsars and to occur above a series of sandstones, quartzites, shales and slates which are equivalent to the Simla slates.

The nature of these Mandhalis is obscure. Oldham, Pilgrim and West all tentatively correlated them with the Blaini and Infra-Krol. If this be so, the Jaunsars must lie as a thrust mass upon Mandhalis, in a manner comparable to their thrust position inferred by Pilgrim and West on the Blaini in the Simla area.

The question of the Mandhalis will be discussed in a later section (page 419). Here I shall just state the view that the Mandhalis may be possibly a series which occurs normally at the base of the Jaunsars. There may, in fact, be two distinct groups of boulder beds and limestones, hitherto both called Blaini, one at the base of the Jaunsars, between them and the Simla slates, called the **Mandhalis**, the other at the top of the Jaunsars, below the Infra-Krol, the Blaini *sensu stricto*.

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 166, (1929).

On this view, the whole outcrop of the so-called Blaini between Simla and south of Badgala which occurs between Simla slates and Jaunsars may be Mandhali. The Jaunsars in this case would be in normal position upon the Mandhalis, without an intervening thrust.

At Badgala Pilgrim and West (page 26) describe the occurrence of slates and a massive limestone which they suggest may be Infra-Krol and Krol. It is possible that these slates and limestone are really equivalent to those found in the Mandhalis of Kalsi.

These authors also (pages 87, 88) describe a sequence of Blaini : Jaunsars : Simla slates at Piran and Pajal which was puzzling on the belief that the Jaunsars normally occurred below the Simla slates. Their suggested explanation (pages 118, 119) is that the Blaini lay upon an eroded overfold in which Jaunsars had been brought abnormally and inverted above Simla slates. If, as is here suggested, the correct sequence is

Blaini,

Jaunsars,

Mandhalis,

Simla slates,

there would be no need to assume the existence of an overfold. But the difficulty is not cleared, since on the south-west and north-east sides of the Mangred Khala, the sequences as mapped are

| *South-west side.* | | *North-east side.* |
|---|---|---|
| Chails | | |
| ........*thrust* | | |
| Jaunsars. | | |
| Blaini.............. | *continuous outcrop* ............ | Blaini |
| | | Jaunsars |
| Simla slates.......... | *continuous outcrop* ............ | Simla slates |

The explanation that I would offer is that the Blaini on both sides of the Mangred Khala is really Mandhali, and that the Jaunsars that are mapped between it and the Simla slates on the north-east side of the river, are a local conglomeratic facies of the Mandhali, such as is often found in the Kalsi area, and by mile 33 on the Chakrata-Mussoorie mule-track.

The relationship between Simla slates and Jaunsars along the Giri river from below Shaluman to Dadahu is little understood Between Mareog and Barog (not the Barog of the Kalka-Simla Railway), typical Chhaosa slates are developed. To the south-

east, the Chhaosa slates are no longer recognisable. Instead, there is seen a series of thin-bedded, tough, dark slates, often well cleaved, and sometimes ramified by veins, lenses and sills of quartz. One mile south-east of Narail, they have a typical Jaunsar aspect, with purple and white, massive, ripple-marked quartzites, (Plate 21, fig. 2). By Siyun, the same slates are barren of quartzites, but contain sheared dolerites. In the Palor ka Khala, these Siyun slates pass upwards to undoubted Jaunsars, with conglomerates and purple phyllites. The slates at Siyun were mapped by Pilgrim and West as Simla slates, but they accord better with a Jaunsar designation.

No boundary between the Jaunsar and Simla series was discernible, though it must occur near the boulder beds and limestones which come down to the Giri river from Badgala. The slates have been mapped in sheets 53 F/5 and 6 as Jaunsars, and in 53 F/1 as Simla slates. The boundary drawn at the junction of sheets 53 F/1 and 5 is purely arbitrary.

East of Dadahu the Jaunsars assume a great thickness and appear to consist of three stages, described on pages 368 to 374. Of these stages, that of Nagthat is most typical of the Jaunsars of the Simla area, but there is a horizon of conglomerates and grits in the Mandhalis that also resembles the Simla Jaunsars. The rocks at Chakrata are Simla slates, and are separated from the Jaunsars by the Tons thrust. The apparent sequence in the Chakrata area is

| | |
|---|---|
| Nagthat stage . . . . . . . . . | Jaunsars. |
| Chandpur stage . . . . . . . . . | |
| Mandhali stage . . . . . . . . . | |
| | *Tons thrust.* |
| Simla slates with occasional Nummulitics. | |

## Blaini on Jaunsars and Simla Slates.

The nature of the relation of the Blaini to the rocks which underlie it is complex. The following is a list of the main types of occurrence of Blaini which occur *in normal succession below Infra-Krol and Krol* :—

(1) ***Blaini on slates similar to Infra-Krol slates*** :

(*a*) Middle reaches of the Blaini river.

(*b*) Spurs north-east and south-east of hill 4,960 feet.

(*c*) Kawal Khal, below height 3,241 feet.
(*d*) Spurs between Jamthali and the Giri river.

These slates should properly be mapped as Blaini but it would be impossible to separate them from the Infra-Krol in places where the Blaini boulder beds or limestones are missing.

(2) ***Blaini** on **Simla** slates :*

(*a*) One mile east of Solon.
(*b*) In the Kawal Kahl at Masria and Mareog.

(3) *Blaini on Jaunsars :*

(*a*) Along the lower reaches of the Blaini river.
(*b*) Between Rerli and Shiwa Kalan, a distance of 22 miles.

By regarding the slates of Infra-Krol type, which are associated with the Blaini, as belonging to the Blaini, no problem is involved as to their relation with the boulder beds and limestones. They may be considered simply as local intercalations of varved sediments below and between tillites.

The problem becomes one of understanding the nature of the occurrence of Blaini both on Simla slates and on Jaunsars.

Bedding discordance has nowhere been seen between the Blaini and the underlying rocks. The unconformity that exists, even though regionally considerable, is not of orogenic violence.

The Blaini boulder beds are made up almost entirely of slates and quartzites derived from the Simla slates and Jaunsars, and clearly indicate extensive erosion of these formations.

Unconformity.

Proof of unconformity has come to light as a result of mapping the great syncline of Tals, Krol limestones, Infra-Krols and Blaini which runs from Giltu ka Tibba (hill 7,005 feet), to Handera Tibba (hill 6,458 feet). The Blaini on the northern limb of this syncline lies on a great thickness of Jaunsars, of the order of 10,000 feet. The Blaini on the southern limb of the syncline rests on at most 2,000 feet (in both cases neglecting the Mandhalis). Some of this discrepant thickness is due to thrusts, since, in the eastern part of the southern limb of the syncline, Tals rest direct on Jaunsars, with Krols, Infra-Krols and Blaini all cut out. In the west, however, the whole Tal-Blaini succession is present, only slightly complicated by minor thrusts, and the

Blaini still rests on a diminished thickness of the Jaunsars. It is the Chandpur stage that is almost completely eliminated.

Since the region from which the Chandpur stage was eroded appears to coincide with the southern limb of the present Tal-Blaini syncline, it follows that the original axis of uplift responsible for the erosion, must have been or less parallel to this limb. This implies that the axis had a Himalayan trend, in contrast to an Aravalli trend.[1] Had there been an Aravalli N. E.–S. W. axis, it would have been impossible for the Jaunsars to be both attenuated by erosion, and fully preserved from erosion, along this single alignment.

In places where the Blaini rests directly on Simla slates, it may be assumed that the Jaunsars had been completely eroded away previous to the deposition of the Blaini. Such erosion must have been local, because, while Blaini rests on Simla slates along parts of the Kawal Khal, and near Solon, it is found on Jaunsars again further to the north-west, along the lower reaches of the Blaini valley. Further, across the Ashmi-Giri rivers to the north-east of Solon and the Kawal Khal, Jaunsars are found in a continuous and wide outcrop which runs without a break from the Gambhar river to south of Badgala.

Accepting that the Mandhalis occur normally between the Jaunsars and the Simla slates, it follows that an unconformity which brings Blaini, Infra-Krols and Krol limestones across the Jaunsars on to the Simla slates, must bring Blaini locally in contact with the Mandhalis. Such contact of Blaini with Mandhalis would lead to great difficulty of mapping, owing to the similarity between the two divisions. It is believed that this *a priori* case may be illustrated by outcrops between longitudes 77° 40′ and 77° 49′, along latitude 30° 33′.

The position may be summarised as follows, accepting here the viewpoint taken up later in the discussion on the Mandhalis.

(1) There is at least a possibility that there are two distinct series of boulder beds and limestones, called Mandhalis and Blaini, in the following sequence :—

Infra-Krols,
Blaini,
Jaunsars,
Mandhalis,
Simla slates.

[1] *See* page 449.

(2) The true Blaini, with overlying Infra-Krol slates and Krol limestones, rests with unconformity upon both the Jaunsars and the Simla slates. This unconformity is great, but in no section has bedding discordance been seen. The folds that led to erosion of the Jaunsars must have been gentle. It is probable that these folds had a Himalayan trend.

## Blaini and Infra-Krol.

As previously stated, slates of Infra-Krol type are often intimately associated with the Blaini limestones and boulder beds.

In the simplest case, Blaini limestone appears to pass up gradually, by increase of shale matter, into pink, greenish, and finally black shales of the Infra-Krols.

The abundant bands of brown-weathering, calcareous, gritty clay-slate which occur in the Infra-Krol may be considered to be small-scale repetitions of the Blaini limestone throughout the lower part of the Infra-Krol succession.

## Infra-Krol, Krol Sandstone and Krol Limestones.

The typical relations of the Infra-Krol to the succeeding stages are seen round Solon. Here the dark or black shales of the Infra-Krols pass up through a transition zone of 100 feet or so to Krol sandstone, and this in turn to more dark shales, before the green calcareous shales and thin-bedded limestones of the Krol A stage set in. Viewed from a distance, as towards the north-west ridges of Rajgarh Hill from Khanog Hill, the change from the black Infra-Krol shales to pale Krol sandstone appears abrupt. When examined at close quarters, the change is found to be gradual.

The Krol sandstone has not been seen east of the western slopes of hill 3,619 feet, nor along the greater part of the north-east flank of the Krol Belt between the Kawal Khal and the Jagar ka Khala. It is only two feet thick in the Giri river half a mile north of Dadahu.

When the sandstone is absent, passage from Infra-Krols to Krol A limestones is shown by a gradual increase in the number of shaly limestone bands. Plate 21, fig. 1, shows the base of the Krol A limestones, where black shales alternate with shaly limestones and calcareous shales.

On account of the varied thickness of the Krol sandstone, Oldham [1] and Pilgrim and West[2] believed that the Krol limestones were unconformable to the Krol sandstone.

This view in my opinion has little justification. Part of Oldham's argument in any case fails, because his objection that the adjacent quartzites in his Carbonaceous series are of far greater thickness than the Krol sandstone with which they were correlated, therefore indicating that considerable erosion of the Krol sandstone had taken place, no longer stands now that those quartzites have been found to belong to a much older Jutogh series.

The intimate interbanding of shale and sandstone and the gradation from Infra-Krol, through Krol sandstone, to Krol A, do not warrant the belief that any break of sedimentary conditions occurred. A truer picture is obtained by regarding the Krol sandstone as a local sandy intercalation amongst the shales and shaly limestones.

If there be unconformity at all, it should be between the Krol sandstone and the Infra-Krols, since discs of Infra-Krol shale are often found in the sandstone, and in one case a wash-out was observed at the top of the Infra-Krols. These phenomena in my opinion prove little except that currents churned up some of the recently deposited black muds.

Medlicott saw no reason for supposing the existence of an unconformity. With that view I am in agreement.

## Krol D.

The existence in the Krol D stage of conglomerates and pebbly sandstones, together with limestone breccias, suggests a slight break in conditions of sedimentation. The break cannot have been important, because nowhere is there any evidence of erosion of the underlying stages of the Krols. The exact relations of these conglomerates to their contemporaneously deposited limestones is obscure. Folding near Mangarh has obliterated all the original sedimentary relationships.

## Krol Limestones and Tals.

Over the greater part of the synclinal basins in which the Tals occur, Lower Tals rest on Upper Krol limestones.

[1] *Rec. Geol. Surv. Ind.*, XXI, p. 138, (1888).
[2] Pilgrim and West, *op. cit.*, p. 134.

South of Guma peak, Upper Krol limestones have been thrust directly on to Upper Tals. This is a tectonic relation.

From south of Khur to Chiyanra, the lower Tals rest on Infra-Krols. This is due probably to a combination of original unconformable overlap of Tals across the stages of the Krol limestones, and of later tectonic elimination. Middlemiss has shown that a slight unconformity exists between the Tal beds and the underlying Massive (Krol) Limestone of Garhwal.

No Tals have been seen on the Krol E limestones south-east of the Giri river, though Subathus occur there. Tals were probably never deposited south-west of the Giri river, since, in those places where they are now found on Krols, they appear to have exerted a protective influence on the underlying limestones and shales, preventing them from folding intricately amongst themselves. It is probable that the strongly folded Krol limestones south-east of the Giri formed more elevated land during the period of Tal deposition, but were submerged below the sea at the end of the Mesozoic.

## Tals and Subathus.

No case has been seen of Subathus resting on Tal beds. This is in contrast to the Garhwal area, where Middlemiss found the two series to be commonly associated.

## Krol Limestones and Subathus.

Between Janot and Sainbar Hill, there is found a collection of black, brown, olive-green and purple, splintery shales, dirty pebbly quartzites and sandstones, and lenticular, blue, shelly limestones which are wedged in the Krol D and E limestones.

At the hill one mile west and south-west of Bongli (hill 6,048 feet on the two-inch map-sheet 313 N. E.), the interbedding of lenticular shelly limestones and brown and green shales with the Krol E rocks is so parallel that the rocks were taken to be authentic fossiliferous Krols. The occurrence of characteristic purple and olive-green cuboidal shales with similar limestones and brown shales at Bagar is strong indication, however, that the whole lot were Subathu.

The fossils are rare and very badly preserved. They are all broken, and, like those in the Subathus, they give the impression of having been mostly oysters that had been current- or wave-tossed on shelly marine banks.

Mr. Wadia has kindly made an examination of these fossiliferous limestones. He writes :—

'Foraminifera are absent, except in one doubtful specimen. Besides many broken bivalve shells (probably *Ostrea*), there is found a turritellid gasteropod, and some black enamelled scales like placoid fish scales. There also occur numerous fish bones, spines and dental plates in a highly fragmentary state in the limestone.

From their general lithological aspect, these limestones may be thought to belong, with equal possibility, to the Triassic or to the grey-black, partly bituminous, shelly, Subathu limestone. On the whole I think the latter supposition is the more probable.'

The decision must rest upon the extremely Subathu-like aspect of the olive-green and purple cuboidal shales, and accordingly these rocks have been mapped as Subathu.

It should be pointed out that the limestones just described, which are regarded as Subathu, as well as true Subathu limestones and the Tal limestones of Garhwal, all contain broken fossils, most of which appear to be oysters. It is most unlikely, however, that the limestones found between Janot and Sainbar Hill are Tal. The Tal limestones are almost invariably sandy, and occur associated with sandstones or quartzites rather than with shales. The Subathu limestones are seldom sandy (though under the microscope, they may be seen to contain a few grains of quartz), and they are always associated with shales.

## The Floor to the Nummulitic Sea.

In Garhwal, Nummulitics rest on Mesozoic Tal beds. In Sirmur State, they are seen on Krol limestones. At Subathu and at Dabra, they occur on Simla slates.

It is clear that a considerable part of the Himalayan area must have been beneath the sea during the early Tertiary, and that there must have been extensive previous erosion to allow for the occurrence of Nummulitics on rock series of such different ages.

The unconformity of Tals on Krols, and the probable formation of the Tals from denudation of closely adjacent montane areas, suggests that erosion in this area did not take place at a single time, immediately preceding the Tertiary period, but was persistent throughout the Mesozoic.

Medlicott's views are expressed on pages 86 and 87 of his memoir. At the time of his survey, Nummulitic rocks had not been found

on Krols, or amongst his crystalline and sub-crystalline rocks to the north-east. Accordingly he was led to believe that

'the pre-nummulitic elevation was effected on the same lines, so to speak, as those which now mark the Himalayan mountain system',

thereby forming a land barrier to the north-east which prevented deposition of the Nummulitics in that direction. As a consequence of the bedding conformity seen between the Subathus and the underlying Simla slates at Subathu, Medlicott claimed that

'The fact of such extensive denudation having affected the older rocks prior to the nummulitic period, implies that these rocks had also undergone disturbance, and it is of importance to be able to indicate the nature of that disturbance; *it was in no sensible degree the disturbance which produces contortion or flexure of strata.*'

Support for this contention was thought to exist in the fact that the Nummulitics show as much disturbance as do the older rocks upon which they rest, from which it was concluded that the older rocks were more or less undisturbed at the time of the deposition of the Nummulitics.

Since the publication of Medlicott's memoir, Nummulitics have been found 'inland' of the main belt of Tertiary rocks. In the Simla area, they have been mapped as far north as Shali peak. They have also been found on the Krol and Tal rocks of the present Krol Belt between Solon and Naini Tal, and occur at Dabra, north of the Tons thrust. The postulated pre-Nummulitic elevation was, therefore, less well-defined as a barrier than Medlicott supposed.

Medlicott's argument concerning the parallelism of dip between the Subathus and the Simla slates clearly does not express the full facts of the case. On page 83, he admits that the entire evidence relating to the geological history of the Nummulitic rocks depends on the section at Subathu. This section cannot be said to be striking, even allowing for the fact that 80 years ago it may have been less obscured by bazar filth, and it is probably a pure accident that just there the Subathus and Simla slates show bedding conformity.

Evidence has been given elsewhere [1] for supposing that in Palæozoic times, the pre-Triassic rocks of the present Himalaya, in the Simla-Chakrata-Naini Tal area, were subject to orogenic activity along north-east to south-west, or Aravalli directions. Middlemiss also noticed that in the Kumaon Himalaya, there was

[1] Auden, *Rec. Geol. Surv. Ind.*, LXVI, p. 461, (1932).

to be found disturbance along north-south lines oblique to the strike usually found in the Tertiary and some of the pre-Tertiary rocks.[1]

The greater general degree of metamorphism, cleavage and crushing shown by the Palæozoic and Mesozoic rocks in the Himalaya cannot be attributed to the mere factor of time, since time alone will leave Algonkian sediments as unaltered as recent ones. Stress must have played a part, and one that is hardly consistent with the total absence of folding or flexure which Medlicott supposed. It is further probable that the Hazara, Chor, Lansdowne and Dudatoli granites may have been intruded towards the end of the Palæozoic.

Medlicott's other point, that the pre-Tertiary and the Tertiary rocks show the same degree of folding, is an indication, not that the earlier rocks had not been previously folded, but that the later Himalayan movements were as intense as any that had preceded, and had caused structures of equal complexity.

It is clear, therefore, that the pre-Tertiary rocks had undergone a more varied history than the simple erosion from approximate horizontality into plateaux and valleys, which had been postulated by Medlicott. Had he omitted the word *flexure*, his position would have been sounder, at any rate for the times occupied by deposition of the Infra Krol, Krol limestones and Tals.

## VIII. METAMORPHISM.

### General.

From the foregoing lithological descriptions, it is seen that the rocks of the Krol Belt show the following grades of alteration :—

> Shales, slates, clay-slates, phyllites, schistose phyllites; sandstones, quartzites, quartz-schists; limestones, recrystallised limestones; dolerites, greenstones.

The whole series is typically one formed under *epi*-conditions. Mica-schists, with index minerals of higher grade, quartzites that have been recrystallised to a new mosaic with complete loss of clastic structures, limestones with calc-silicate minerals, and hornblende-schists, have nowhere been found.

[1] *Mem. Geol. Surv. Ind.*, XXIV, pp. 125-129, (1890).

The argillaceous rocks have not been metamorphosed sufficiently for the microscope to be of much value in determination. Most of the slates and phyllites, which in hand-specimen are characteristic, are not particularly distinctive in thin sections. The differences amongst these argillaceous rocks are on the whole megascopic, rather than microscopic.

Amongst the argillaceous rocks, newly-formed quartz, sericite and chlorite are fairly universal. Blasto-biotite has not been seen.

Some of the quartz-schists of the Jaunsars are sufficiently metamorphosed for the clastic structure to be almost obliterated. Mosaics of recrystallised quartz are frequently found, but never completely throughout the body of the rock.

In the limestones may be seen idioblasts of calcite. Many of the Upper Krol limestones have been completely recrystallised, and infested with sigmoid veins of calcite (43·758), but, even when siliceous impurities are present, there has been no sign of the formation of calc-silicate minerals. A striking feature of most of the limestones is the recrystallisation side by side of quartz and carbonate, and the frequent replacement of quartz by carbonate. It is clear that stress has acted on these rocks without the influence of any considerable temperature, since wollastonite is not formed.

The dolerites are readily susceptible to change, but, in spite of uralitisation and saussuritisation, they can always be recognised as basic hypabyssal intrusives.

## Distribution of Metamorphic Effects throughout Succession.

*Tabular statement of Metamorphic Effects.*

| | Schistose phyllite ; knotted slate. | Phyllite. | True slates with oblique cleavage. | Clay-slates. | Crushing parallel to N.E.-S.W. directions. | Injection with quartz-veins due to crushing. | Flowed limestone. | Jointing. |
|---|---|---|---|---|---|---|---|---|
| Nahans . . . . | | | | | | | | Coarse and irregular |
| Kasaulis . . . . | | | | * | | | | Fairly good. |
| Dagshais . . . . | | | | | | | | Irregular. |
| Subathus . . . . | | sub-phyllitic. | | * | | * | | Very irregular. |

*Tabular statement of Metamorphic Effects*—contd.

| | Schistose phyllite; knotted slate. | Phyllite | True slates with oblique cleavage. | Clay-slates. | Crushing parallel to N. E.–S. W. direction. | Injection with quartz-veins due to crushing. | Flowed limestone. | Jointing. |
|---|---|---|---|---|---|---|---|---|
| Upper Tals . . . | | * | | * | | * | | Strong clean-cut. |
| Lower Tals . . . | | | * | | | * | | Strong clean-cut. |
| Upper Krol Limestone . | | | | | | | | Irregular. |
| Red shales . . . | | | | | | | | |
| Lower Krol limestone . | | sub-phyllitic. | * | * | | * | * | |
| Krol sandstone . . | | | | | | * | | |
| Infra-Krols . . . | * | * | * | * | | * | | |
| Blaini . . . . | * | * | * | * | * | * | | |
| Jaunsars . . . | * | * | * | * | * | * | * | Strong clean-cut. |
| Mandhalis . . . | * | * | * | * | | * | * | |
| Simla slates . . . | | * | | * | | * | * | |

The above table shows that it is impossible to differentiate the rocks of the Krol Belt by their metamorphic condition.

No rigid list of characters can be assigned to any particular series of rocks present in the Krol Belt. There is no regular decrease in metamorphism, varying directly and discontinuously, with the division of the rocks into discontinuous series.

What is not seen in the table is the fact that most of the series show rocks of varied degrees of metamorphism.

In the Simla slates and Kasaulis, soft green needle-shales occur interbedded with clay-slate.

In the Jaunsars occur sandstones, quartzites and quartz-schists in close association. Single beds of quartzite may be marked out by extreme permeation with vein-quartz, due to crushing, while adjacent beds are free from veining. Clay-slates, slates, phyllites and chlorite-schists all occur close together, the green beds being particularly susceptible to alteration.

In the Blaini, red shales occur with banded slates. In the Krol, marmorised Krol C limestone may be seen to lie on unaltered red shales which have been penetrated by sheared greenstones (dolerites).

In the Subathus may be found gradation from soft purple and green shales to hard, tough, phyllitic clay-slates, penetrated with veins of quartz. Middlemiss noticed the same feature in the case of the Subathus in British Garhwal.[1] Purple slates that he had previously mapped as belonging to his 'Purple Slate' series[2], he later found were metamorphosed nummulitics. Griesbach [3] working in the Hundes wrote as follows:—

'the nummulitic rocks of Hundes (north of Niti) have in large measure been converted into a semi-crystalline formation, which one would naturally identify with some of the lower palæozoics (haimantas) which they resemble, were it not that on the one hand their position between the cretaceous and the younger middle tertiaries and on the other, indistinct traces of *nummulites*, determined their geological age accurately'.

Griesbach assigns this particular metamorphism to the abundant basic eruptive rocks found in the Hundes. The parallelism with the phyllitised Subathu rocks of Dadahu and in British Garhwal is perhaps remote, although east of Dadahu there have been found a large number of sheared basic leucophyres. Since, in general, basic rocks do not effect much change on the adjacent sedimentaries, it is possible that the metamorphism of the Nummulitics at Hundes, as well as along the Himalayan foothills, may be only indirectly connected with the associated igneous rocks. Both metamorphism and intrusion may have originated from the same causal stresses.

## Distribution in Space.

Regarding the rocks of the Krol Belt in relation to neighbouring zones, the following divisions may be made out:—

(1) *Schist zone:* to the north-east; showing phyllites, schists often with index minerals; recrystallised quartzites; *epi*- and *meso*-conditions.

(2) *Krol Belt:* great variation in character of metamorphism; typically of *epi*-type.

(3) *Zone of Tertiary rocks*: to the south-west; generally non-metamorphosed, but locally indistinguishable from *epi*-type rocks of the Krol Belt.

[1] *Mem. Geol. Surv. Ind.*, XXIV, p. 72, (1890).
[2] *Rec. Geol. Surv. Ind.*, XX, p. 33, (1887).
[3] *Mem. Geol. Surv. Ind.*, XXIII, p. 45, (1891).

This division into three zones is not absolute. Rocks of *epi-*type occur in all three zones. Further, along the Krol Belt, there is longitudinal, or strike, variation in intensity of metamorphism. The Infra-Krol and Krol A stages become more altered towards the south-east.

## Discussion.

The metamorphic condition of these rocks is of interest in two connections, firstly, the bearing it has on correlations, secondly, the question of its cause.

One of the arguments used by Pilgrim and West in connection with abolishing the original correlation made by Medlicott of the rocks at Simla with those at Solon was based on the different metamorphic condition of the rocks of the two areas.

Referring to the Simla slates, Blaini, Infra-Krols and Krol limestones, they state on page 6:—

> 'It is a noteworthy fact that none of the rocks so far mentioned is truly metamorphic. Not only are there no secondary minerals developed, but further, the Simla, Blaini and Infra-Krol series, though containing rocks often resembling slates, have no slaty cleavage and we have found no evidence of any planes of crushing which do not coincide with the planes of bedding; neither is there any crystalline structure or evidence of flow in the limestones; while the Krol sandstone is obviously not a metamorphic quartzite.'

They intended to emphasise the different grades of metamorphism between the Simla and Solon rocks, concluding (1) that the more metamorphosed rocks were the older; (2) that juxtaposition of rocks of different degrees of metamorphism must be accounted for by thrusts, that had brought rocks of different ages into abnormal association.

Had one's attention been confined to the generally unaltered rocks of the Tertiary zone, or, as was that of Pilgrim and West, to the schist zone, the occasional presence of more or of less altered rocks would not have upset the broad impression of constancy in character gained from these areas as a whole. Occasional traverses from either of these areas across adjacent zones would doubtless suggest a contrast sufficient to permit the belief in differences in kind between them. Work along the Krol Belt has shown, however, its transitional character to the zones that border it, and there has proved to be far less conviction as to the rigidity of distinction, both correlative and metamorphic, of the rocks of the three zones.

As seen from the general statement made above, the criteria assumed in the quotation just given are not valid. Viewing the

rocks of the Krol Belt as a whole, there is in many places an approximation to the metamorphic grade of a considerable quantity of the rocks found in the area described by Pilgrim and West.[1]

The contrast between the garnet- and staurolite-schists of the Jutoghs with the shales of the Infra-Krols near Solon is undeniably great, but it must be recognised that this is the extreme contrast. Elsewhere the rocks of the Krol Belt become more metamorphosed, while the Jutoghs, away from the influence of the Chor granite, tend to lose their index minerals. The Jaunsars of the Krol Belt and the Chails of the area mapped by Pilgrim and West are in some places practically indistinguishable, as on Rigana Dhar and at Tikar.

It is not intended to imply that a correlation between the rocks at Simla and Solon should be reverted to, or that thrust-planes are not present. Pilgrim and West found definite structural features, indicative of the existence of thrust-planes, particularly at the base of the Chails. In the Deoban area, Mr. West has recently found mylonites below the Chail thrust.[2] Moreover, these authors obtained evidence of elimination of beds by overlap, which coincided with these structural features.

It is, hoped however, to indicate that the differences between the rocks of the Krol Belt and of the adjacent north-eastern area are not absolute, and that the question of age cannot satisfactorily be told by considering solely their metamorphic aspect.

### *Gradation.*

There is a large body of opinion amongst geologists, championed by Gregory[3] and Kober[4], that all extensive areas occupied by crystall-

[1] It should be expressly pointed out that the criteria they assumed were valid for the few sections in the Krol Belt that they visited. That it has been found that these criteria do not hold, is solely the result of working in detail over a larger area than they were able to visit.

[2] *Rec. Geol. Surv. Ind.*, LXV, p. 130, (1931).

[3] 'Structure of Asia', p. 7, (1929). 'General Stratigraphy', p. 7, (1931).

[4] Kober may be quoted. His claim is that *kata*-rocks (*hypo*-rocks of Fermor) of regional extent, have only been found for certain in the pre-Cambrian. He accepts that *meso*- and *epi*-rocks have been formed as a result of the Mesozoic and Tertiary alpine tectonics. In 'Das alpine Europa' (Berlin, 1931), p. 18, he states :—

> 'Eine einheitliche junge alpine Metamorphose geht über die Metamorphiden des alpinen Orogens hinweg. Kristalline Schiefer der mittleren Tiefenstufe entstehen in regionaler Metamorphose. Diese ist Bewegungsmetamorphose (Dynamometamorphose), auch Belastungsmetamorphose. Wahrscheinlich werden diese Zonen schon vor der Oberkreide von den grossen Schubmassen der Zentraliden überschoben, gelangen so in die Tiefe des alpinen Troges.'

On pp. 268, 274, he suggests that the alpine *meso*-metamorphism may pass to *kata*-type in depth.

See also Kober, 'Der Bau der Erde', 2 Aufl., p. 79, (1928).

ine schists must be pre-Cambrian. This is in contrast to the views of many Alpine geologists, including F. E. Suess, Argand and Staub. Analogies of the Himalaya with the Alps may perhaps be considered too remote, but we may take examples from the Himalaya themselves, to show that the relation between areas of schists and of less altered slates and phyllites, for which there is no reason to suppose a pre-Cambrian age, is often intimate.

Dr. A. M. Heron [1] has described the relation of Triassic and Jurassic rocks north of Mount Everest to their metamorphosed equivalents actually on the mountain-side. A series of shales and limestones, Triassic and Jurassic in age, has been permeated with tourmaline-granite which has metamorphosed them to mica-schists and banded calc-silicate rocks. He writes :—

'In the above-described sections the change from sedimentary to metamorphic rock is very clearly seen, taking place gradually in magnificent cliff faces with no break nor discordance in the stratification ; from a short distance away it is indeed often impossible to say whether one is looking at limestone or calc-schist.'

Hayden [2] criticises Griesbach's assignation of the latter's *Vaikrita system* to the pre-Cambrian on the grounds that similar rocks are found in the Sutlej valley and the Spiti river which should be regarded as Haimantas. He states in regard to these localities :—

'the kyanite-schists and garnetiferous mica-schists are found to pass horizontally into less altered phyllites and clay-slates belonging to the cambrian system and corresponding to Mr. Griesbach's middle haimantas. Similarly, highly altered staurolite and kyanite schists are found between Asrang and Pangi, where the intrusive biotite granite is found in contact with the cambrian slates.'

Coming closer to the area with which we are directly concerned, to the schists associated with the Dudatoli granite, Middlemiss states[3] :—

'I may here emphasise two points—first, the schist found near the gneissose granite is entirely a thorough crystalline schist, a fact needing no microscope to demonstrate ; and secondly, along a line of country, where rock is exposed at every step, it is seen that this culminating intense form *graduates* into a wide-spread less intense form, and that in turn *graduates* into ordinary slates and quartzites.'

Finally may be quoted Mr. D. N. Wadia's description of the rocks in the Hazara [4] area, of late pre-Cambrian and of Cambrian age.

'There is not much doubt that by far the largest part of the schist zone of Hazara and Karnah represents regionally as well as thermally altered Dogra (Hazara)

[1] *Rec. Geol. Surv. Ind.*, LIV, p. 223, (1922).
[2] *Mem. Geol. Surv. Ind.*, XXXVI, p. 9, (1904).
[3] *Rec. Geol. Surv. Ind.*, XX, p. 137, (1887).
[4] *Op. cit.*, LXV, p. 200, (1931).

slates. Middlemiss .... entertained no serious doubt as to their identity. The perfectly uniform and unvarying argillaceous composition of Dogra slate from place to place, save for the ubiquitous dolerite dykes and rare thin limestone layers, is one unfailing criterion. In the present area, it is permeated with granitoid gneiss intrusions (Central Himalayan gneiss), and the contact effects on the slates, converting them into phyllites, hornfels, and thinly foliated garnetiferous biotite-schists, with occasional staurolite, round the larger intrusions, are well seen.'

Three facts are evident from these accounts. Firstly, schists over extensive areas may be of Palæozoic, or even later age, an opinion that is held by most alpine geologists. Secondly, these schists grade into slates, phyllites and limestones, of types prevalent throughout the geological succession in the Himalaya. Thirdly, the intense, schist form of alteration is related in all cases to the intrusion of granite; while the less intense, phyllite and slate, forms of alteration are connected with the general regional stresses operative at the time.[1]

Besides the lateral variation in metamorphic intensity described in the quotations given above, there is also variation in dip section. Rocks of markedly different metamorphic aspect may be seen to be interbedded, and in such a close manner that their juxtaposition cannot be explained by thrusting or by isoclinal folding of distinct rock series.

Metamorphism of low-grade, *epi*-type, and approaching *meso*-type, appears to be selective, being greatest, in the same locality, in those rocks that were presumably richer in unstable minerals, or had a higher water content. It is only in the highest grades that external influences are intense enough to overcome small differences between beds of approximately the same facies, and bring all the rocks to a common level of reconstruction.

### *Position and age of granites.*

**Granites in cores of synclines.**

It is a singular feature that the Dudatoli and Lansdowne granites occur synclinally at the top of a synclinal succession of slates and schists. The same relationship may obtain with the Chor granite. It is not at all improbable that, since the great series of Jutogh

[1] These accounts would appear to militate against any suggestion that thrusts separating rocks of dissimilar metamorphic grade had been missed by the observers. The stress laid upon continuity of exposures shows that the observations were critical, and the whole trend of these author's accounts disposes of the possibility that the wish was father to the thought, in describing this gradation.

rocks at Simla occurs in synclinal form, they may have originally been capped by a continuation of the Chor granite, and may have owed much of their metamorphism to a granite which has now been removed. Oldham [1] postulated this, but the view has since been discarded[2], on the grounds that an intrusive mass is not capable of producing wide-spread metamorphic effects, such as are found in the Jutoghs. The occurrence of these gneissose granites in the cores of synclines certainly demands some connection of the granite with the general processes of regional metamorphism. It is probably nearer the truth to picture both the intrusion of the granites (or their self-generation, 'inborn', so to speak, in the cores of the folds[3]) and the general regional metamorphism as part effects of a wider cause.

Age of granites.

I have given reasons elsewhere [4] for believing that some of the gneissic granites of the outer Himalaya were Carboniferous or slightly older, and were connected with tectonic activity along the Aravalli axis. Further, since the Hazara granite intrudes the Dogra slates, which are pre-Cambrian and Cambrian in age, it is permissible to regard this granite as post-Cambrian. The general similarity in character and manner of occurrence of the Hazara, Chor, Lansdowne and Dudatoli granites suggests that their correlation is permissible, and that they were intruded during the Palæozoic era. The evidence, which is not absolute, is discussed in the paper quoted.

Difficulties arise if an attempt is made to narrow down the time limit still further. The Jaunsar arkoses indicate the presence of an earlier granite, but the Jaunsars are affected by the same Aravalli orientation that is seen in the Lansdowne granite. This orientation in the Lansdowne granite may presumably be connected with its intrusion tectonics. It is tempting, therefore, to regard the intrusion of the granite as immediately post-Jaunsar (? post-Devonian) in age, since both granite and Jaunsars are affected along the same tectonic directions. As opposed to this reasoning, it is possible to assume rejuvenation of activity along the Aravalli axis, and to object that similarity of orientation is not proof of tectonic contemporaneity.

[1] *Rec. Geol. Surv. Ind.*, XX, p. 148, (1887).

[2] *Mem. Geol. Surv. Ind.*, LIII, p. 8, (1928).

[3] This is not the place to enter into a discussion on the formation of granites. It must suffice to say that the appearances in the field do indeed suggest that simple intrusion from some totally foreign source is not a complete explanation of some of these occurrences of granite. Compare Middlemiss, *Rec. Geol. Surv. Ind.*, XX, p. 140, (1887).

[4] *Rec. Geol. Surv. Ind.*, LXVI, pp. 461-471, (1933).

*Application to Krol Belt.*

In the Hazara area, Mr. Wadia has the following succession[1] :—

Cambro-Silurian.

Dogra slates (Cambrian and pre-Cambrian, and probably equivalent to the Simla slates).

Salkhala series (Archaean).

Wadia and West[2] are agreed that the Jutoghs of the Simla area are equivalent to the Salkhalas of Hazara. The Jutoghs must therefore be regarded as Archaean.

Mr. West[3] has related the higher grades of metamorphism of the Jutogh series to the intrusion of the Chor granite. It is known also that the Dogra slates owe their metamorphism to the Hazara granite. It follows that, besides the Archaean formations, which perhaps were schistose before the intrusion of the gneissic granites, there was a later, post-Cambrian, development of schists which was directly connected with these intrusions.

We have, therefore, to consider the regional metamorphism of the Dogra slates, and possibly also some of the metamorphism of the Jutoghs, as Palæozoic. We know also that the Krol, Tal and Tertiary rocks have been metamorphosed as a result of the Tertiary orogenic movements. Four factors must therefore be disentangled :—

(1) The possible existence of Archaean schists, of *meso*-type.

(2) The broad regional metamorphism of the Palæozoic sediments, of *epi*-type.

(3) The locally intenser grade of this metamorphism in association with gneissic granites, of *meso*-type.

(4) The later metamorphism resulting from the Tertiary orogenic movements, of *epi*-type :

(*a*) acting on Palæozoic sediments already affected by the earlier metamorphism ;

(*b*) acting on Infra-Krol, Krol, Tal (late Palæozoic and Mesozoic) and Tertiary sediments, which had not been deposited at the time of the earlier metamorphism.

[1] *Rec. Geol. Surv. Ind.*, LXV, p. 202, (1931).
[2] *Op. cit.*, p. 126, (1931).
[3] *Mem. Geol. Surv. Ind.*, LIII, p. 60, (1928).

The effects of the Tertiary movements on Infra-Krol, Krol and Tal sediments has been to cause slaty cleavage, the formation of phyllites and locally of sub-schistose rocks. Limestones have flowed and recrystallised, and quartzites have been permeated with vein quartz. The effects have been such that slates in the Infra-Krol are similar to some in the Simla and Jaunsar series, and may even be confused with sub-schistose rocks in the Chails. Tals resemble Jaunsars, not only lithologically, but also in metamorphic aspect. Krol A slates resemble green slates in the Jaunsars. Phyllitised Subathu shales may be confused with rocks in the Infra-Krol and Jaunsar series.

**Nature of Tertiary metamorphism.**

It is seen that sediments deposited after the regional Palæozoic metamorphism have to a large extent attained the same physiognomy as those that have undergone both the earlier, Palæozoic, and the later, Tertiary, metamorphism. *Epi*-conditions prevailed throughout. The superposition of a later *epi*-metamorphism on an earlier metamorphism of the same type has had no additive effect.

No granites were intruded amongst the rocks of the Krol Belt. Granites and *meso*-grade schists occur only in the zone to the north-east of the Krol Belt.

It is of interest, therefore, to see whether the rocks of the Krol Belt give any information as to the previous existence in this neighbouring zone of rocks of higher grade, *meso*-type metamorphism. Conglomerates are common throughout the geological succession in the Simla-Chakrata hills. Evidence should be obtained, by examining the boulders and pebbles, whether any high-grade metamorphic rocks were exposed to denudation, or were formed at all, prior to the deposition of the rocks containing the pebbles.

**Evidence of pebbles in conglomerates.**

It is a striking fact that, except in one rock slice of the Blaini boulder bed, no single instance has been found either in the field, or in rock-slice, of any true schists or metamorphic rocks of *meso*-type being included in the pre-Tertiary conglomerates. Phyllites, black (? carbonaceous) slates, and sandstones are found abundantly as fragments in the Simla slates, the Morar-Chakrata beds (largely Simla slates), and the Blaini ; but never schists, never garnets, and only one case of a completely recrystallised mosaic-quartzite (slice 21999). The boulders in the Blaini are almost entirely dark slates, sandstones and quartzites, all types which can be matched

in the Simla slates and Jaunsars. The boulders in the Jaunsars are mostly of material derived from penecontemporaneous erosion, while the abundant pebbles of vein-quartz perhaps indicate a granite-pegmatite source. In the Jaunsar arkoses are found plagioclase felspar and tourmaline. In the Tal arkoses occur microcline and tourmaline. The provenance of these minerals was almost certainly granitic.

Pebbles of gneissic granite, similar to the Hazara granite, have been noticed by Mr. Wadia in the Agglomeratic Slate of Kashmir, *i.e.*, in rocks of Upper Carboniferous age. A pebble of albite-oligoclase-granite has been found in the 'volcanic breccia' of Garhwal, which is either Carboniferous or pre-Carboniferous in age.

Aside from these indications of the existence of granites, there is extremely scanty indication of any derivative environment to the whole sequence of rocks in the Krol Belt other than that showing *epi*-metamorphism. Not until the Dagshais, of Oligocene or Miocene age, are there found metamorphic rocks and minerals of *meso*-type. In the Dagshais and Kasaulis, garnet is abundant. In the Sutlej rocks, garnet and pebbles of recrystallised quartz-schist may be found.

Professor F. E. Suess.

A similar feature has been noticed by Prof. F. E. Suess[1]. He has been criticised, amongst others by Gregory[2], for supposing that the schists and gneisses of Moldanubian type in Bohemia are equivalents of Barrandien Palaeozoic sediments, metamorphosed by the Hercynian revolution. Referring to the non-metamorphosed pre-Cambrian and early Palaeozoic equivalents of Central Bohemia, he states :—

> 'Conglomerates and graywackes in which crystalline constituents are entirely wanting are rather rare. But a geologist rambling over the huge stretches of the Algonkian and early Cambrian of Bohemia will be deeply impressed by the fact that the innumerable beds of conglomerate consist exclusively of pebbles of slate, lydite, diabase, spilite, and a few others from the Algonkian itself in astounding monotony, and that crystalline constituents are entirely absent. It appears almost as if at that time no other kind of rocks had been in existence.'[3]

[1] *Geol. Mag.*, LXIX, p. 431, (1932).

[2] 'Dalradian Geology', p. 24, (1930).

[3] I may perhaps be excused in quoting from my own Progress Report, p. 29, for 1931, where less graphically and less clearly expressed, I wrote :—'There is as well a total failure of any fragments of schist in the boulder beds and conglomerates of the rocks so far seen, as if the periods of metamorphism post-dated the formations of the succession.' The impressions gained in the two cases are so strikingly similar that they deserve recording, because of their independent formulation.

This evidence anomalous.

The facts as related to the Himalayan area present anomalies. The absence of pebbles and boulders of schist and metamorphic quartzites in the Simla and Jaunsar series would seem to indicate either that no area of metamorphic rocks of *meso*-type was exposed to denudation at the time of deposition of the sediments, or that metamorphism of *meso*-type had not then occurred. Yet there is evidence in the Carboniferous boulder beds that granites had intruded previously. Moreover, the pebbles of gneissic granite in the Agglomeratic Slate suggest the previous intrusion of precisely those granites that were associated with the regional metamorphism of Dogra slates. If gneissic granites are found as pebbles, it might be expected that schists would also be found. It is true, as Mr. Wadia has suggested to me, that schists would readily disintegrate during transportation, but at least index minerals, such as garnet, should occur in the sediments derived from the schistose areas.[1]

The existence of post-Cambrian granites to some extent explains the difficulty, since the formation of schists with higher grade index minerals would have been entirely subsequent to the deposition of the Simla and probably the Jaunsar series. Even so, the boulder beds, such as the Agglomeratic Slate, the Blaini, and the 'volcanic breccia' of Garhwal, should contain rocks with metamorphic aspect, since they were presumably formed after metamorphism of the rocks, or equivalent rocks, from which they were derived.

It must be assumed that the zone of granite intrusion prior to the altogether later Tertiary thrusting, was far removed from the rocks now found in the Krol Belt. The Carboniferous boulder-bearing rocks must have been derived locally from rocks of low-grade metamorphism in the Simla and Jaunsar series, with only occasional stray pebbles of resistant granite derived from the zone of granite intrusion. Even in Kashmir, where the Agglomeratic Slate was evidently closer to the area of granitic intrusion, Middlemiss[2] mentions only the following pebbles :—quartz, feldspar, slate,

[1] De Terra ['Geologische Forschungen im westlichen K'un-lun und Karakorum Himalaya' Berlin, p. 45, (1932)] notes the following rocks to be present as pebbles in the basal conglomerate of the Kilian series (Old Palæozoic) in the K'un-lun :—gneiss, chlorite-quartz-schist, mica-schist, and vein-quartz. He remarks that the conglomerate is locally coloured red on account of the oxidation of biotite in the pebbles of mica-schist, thereby emphasising the detrital occurrence of this rock type. The provenance of these pebbles is from the Karakasch series, which is probably pre-Cambrian.

[2] *Rec. Geol. Surv. Ind.*, XL, p. 233, (1910).

quartz-porphyry, occasional quartzite, pegmatite and tourmaline-granite.

Archaeans must have formed a basement and margin to the area of deposition of the Simla slates, but they have left no recognisable traces of the characters they now exhibit. Possibly they occurred then as phyllites rather than as schists.

## IX. MANDHALIS.

### Significance of Boulder Beds.

The Mandhali beds have offered a problem of great difficulty. Allusion has already been made to them on pages 368 and 396 . The previous workers concerned with this group of rocks are Oldham (1883-1888), Pilgrim and West (1928), and West (1931). In 1888, Oldham summed up their characters as follows[1] :—

> 'The group....is of the most protean character, consisting of quartzites, slates, limestones, conglomerates and boulder beds in most variable proportions and interstratified in the most extraordinary manner; it being not uncommon to find slates or even limestone interbedded with coarse grits or conglomerates. This variability appears to be due to the fact that it has been deposited in close proximity to land, and always contains a large proportion of debris derived from the older rocks of the neighbourhood. Thus in Northern Jaonsar and Bawar, where it rests on the Deoban limestone fragments of that rock are extremely abundant in it and there are several beds of a conglomerate composed exclusively of rounded boulders of the Deoban limestone imbedded in a matrix of the same rock in a finely comminuted form, while in Southern Jaonsar, where it rests on the quartzites of the Jaonsar series the group consists almost entirely of coarse quartzites and grits.
>
> But the great characteristic of the Mandhali group is the presence of boulder beds of the same type as that of the Blaini group. So great indeed is the similarity that in more than one case an exposure of this group has been described as Blaini.'

Oldham finally correlates these beds with the Blaini.

With this correlation, Pilgrim and West are in agreement, although, on account of the thickness of the Mandhalis, these authors were inclined to regard them as equivalent to the combined Blaini and Infra Krol.[2]

[1] *Rec. Geol. Surv. Ind.*, XXI, p. 136, (1888).
[2] *Mem. Geol. Surv. Ind.*, LIII, p. 43, (1928).

There are three distinct rock facies which have to be considered in a discussion of the Mandhalis :—

(1) Limestones.
(2) Pebble beds and conglomerates.
(3) Boulder beds.

Most prominence has been given to the boulder beds, the presence of which has led to the correlation of the Mandhalis with the Blaini. The associated limestones, pebble beds and conglomerates have been variously grouped with the Mandhalis, Jaunsars and Chails according to the impressions gained from single exposures, where one or other or all of the above facies are prominent.

It is true that boulder beds are striking rocks which at once attract the eye. Moreover, the origin of these boulder beds, whether glacial, volcanic or otherwise, is certainly one that implies somewhat abnormal conditions of sedimentation. In proportion to this abnormality of origin, it may be thought that the causal factors would be rarer. Consequently, a series of boulder beds, with an abnormal manner of origin, might be considered to be probably contemporaneous.

This was the basis of the reasoning of Oldham, who wrote as follows[1] :—

> 'If we take the glacial origin of the two as proved, this in itself would establish the contemporancity of the two groups of beds which outside evidence places between the Deoban and the upper part of the carbonaceous system.'

The premises do not appear to me to be sound. In New South Wales, Australia[2], there are five glacial horizons between the Upper Carboniferous and the Upper Permian. During the Pleistocene glacial period of the European Alps, there were four periods of glaciation, separated by interglacial periods.

Oldham himself, on pages 132 and 133 in the same paper just quoted, seemed satisfied, in spite of a certain element of doubt, that two exposures of boulder-bearing rocks did properly occur low down in his Jaunsar succession.

I have mentioned the occurrence of boulder beds in the Nagthat beds on page 373. In Garhwal I have noticed a boulder bed in the middle of Middlemiss's Purple Slate series[3], which occurs above and is quite distinct from, the 'volcanic breccia'.

[1] *Rec. Geol. Surv. Ind.*, XXI, p. 137, (1888).
[2] 'Explanatory Notes to New Geological Map of Australia', Table E, p. 62, (1932).
[3] *Rec. Geol. Surv. Ind.*, XVIII, p. 74, (1885); *op. cit.*, XX, p. 34, (1887).

In the Hazara area, Mr. Wadia has found a conglomerate, 120 feet thick, which occurs above the Dogra slates (=Simla slates) and at the base of a series of phyllites and quartzites, called the Tanols.[1] At the top of the Tanols near Talhatta, is another conglomerate, possibly equivalent to the Blaini.

The following correlation is suggested :—

| Hazara. | Simla-Chakrata hills. |
|---|---|
| Talhatta conglomerate | Blaini. |
| Tanols | Nagthat and Chandpur stages. |
| Conglomeratic boulder bed | Mandhali stage. |
| Dogra slates | Morar-Chakrata beds (Simla slates). |

Boulder beds may be formed under very varied conditions. Middlemiss assigned a volcanic origin to the breccia in Garhwal. This is exactly similar in appearance to the Blaini boulder bed, which has been regarded as glacial. Later, when working in Kashmir, he was unable to decide whether the Agglomeratic Slate was of glacial or of volcanic origin. Mr. Wadia has recently found traces of original glass in this Agglomeratic Slate and concludes that it is probably volcanic.[2] The intimate association of glacial and volcanic rocks is well displayed in the Permo-Carboniferous succession of New South Wales.

We should expect every gradation between true tillites, fluvio-glacial beds and 'ordinary' conglomerates. Certainly in the case of the Mandhali and Blaini boulder beds, conglomerates can be seen to grade into boulder beds. Further, the tuffs associated with the Chandpur beds prove definitely that volcanic activity occurred, and at a time, in my opinion, between the deposition of the Mandhalis and the Blaini. It is quite possible that agglomerates may have been formed earlier and later than the tuffs, contemporaneously with the supposed glacial tillites.

On the grounds, therefore, both of origin and of frequency, it cannot be asserted positively that the boulder beds of this region are necessarily glacial, and necessarily of one period.

I can offer no absolute proof that the view previously held, namely, that the boulder beds are glacial and all Blaini, is erroneous, because the sections now exposed are disturbed, and by them selves do not permit of certainty. But this former view has led to difficulties.

[1] *Rec. Geol. Surv. Ind.*, LXV, pp. 204-206, (1932)
[2] *Mem. Geol. Surv. Ind.*, LI, p. 235, (1928).

## Consequences of Mandhali-Blaini Correlation.

If the correlation of the Mandhalis with the Blaini is accepted, two difficulties are at once evident:—

(1) The Mandhalis south of Chakrata appear everywhere to dip synclinally below the Jaunsars, and are, therefore, on this supposition, overlain by rocks older than themselves. The whole syncline of Jaunsars, normal Blaini, Infra-Krols, Krol limestones and Tals must rest as a thrust mass, or *nappe*, upon the Mandhalis.

(2) There must be two totally distinct facies of the Blaini now in close proximity:

 (*a*) the thin boulder bed and limestone, which runs from Chandpur peak to Shiwa Kalan;

 (*b*) the extremely complex series of beds called Mandhali.

## Reasons against Mandhali-Blaini Correlation.

There is no sign of the thrust plane that would be required to separate the Mandhalis from the overlying Chandpur beds, if the Mandhalis and the Blaini are regarded as equivalent. The quartzite associated with the Bansa limestone is, it is true, often markedly schistose, but not more so than many of the quartzites in the Mandhalis themselves and in the Nagthat stage. Thrust planes are admittedly often very difficult to locate, since they may leave little trace of their action in the rocks brought into abnormal juxtaposition. It seems irrational, however, to assume a thrust solely because of a lithological change from a series of limestones, phyllites, quartzites and boulder beds up to a series of banded quartzite and phyllites, with tuff beds, unless the ages of these contrasted rocks are known. It has just been argued that boulder beds are a common feature in the Himalaya and that age cannot be told from their occurrence.

The associations of the Mandhali and Blaini rocks may be summarised as follows:—

(1) *Mandhali.*—Characterised by a complex association of dark limestones, often sandy, and often marmorised, phyllites, grits, boulder beds, conglomerates, schistose quartzites, apparently underlying the Chandpur stage. Boulder beds full of limestone fragments and limestone of *in situ* growth.

(2) *Blaini.*—Pink siliceous limestone, not sandy, associated with boulder bed in which limestone fragments are very rare. The limestone and

boulder bed, if both present, are always together. Overlies the Nagthat beds, which in turn rest on the Chandpur stage.

This Blaini boulder bed, with its pink siliceous limestone, is always overlain by Infra-Krol and Krol rocks, the three stages forming the only readily recognisable sequence in the whole of the Krol Belt. East of longitude 77° 30′, the Tal beds form an additional and also distinctive series above the Krol limestones, the sequence eastwards invariably being Blaini : Infra-Krol : Krol : Tal.

This Blaini : Infra-Krol : Krol : Tal succession is 'normal' in the sense that it is almost certain that the stages in it are in their original order of deposition, and are unaffected by thrusts of any regional magnitude. It may be taken as the standard of reference for the Krol Belt. The relationships between the various stages in it are constant, and their mapping, apart from physical exertion, is always easy.

Contrasted with this orderly sequence, of which the Blaini is the invariable basal member, is the disorder that prevails amongst the Mandhali rocks, and the fact that the Mandhalis are overlain by a group of rocks totally distinct from the Infra-Krol to Tal succession.

Since, then, we find that the Mandhalis, in the region where the whole of the geological column is best developed, occur in an association that is altogether foreign to the Blaini and overlying rocks, we may conclude that the Mandhali-Blaini correlation is probably unsound.

Apparent support for the Mandhali-Blaini correlation is found along the tract bordering the Krol thrust. Here both the Chandpur and the Nagthat stages are almost absent, and Blaini and even the Krol are brought into contact with Mandhalis, causing admitted embarrassment. But the tract bordering the Krol thrust is so clearly a zone in which thrusts are common and abnormal juxtapositions occur, that it can hardly be considered reasonable to consider only the evidence of such a tract, when fuller evidence is to be obtained further north.

## Field Relations to North-West.

At the time of mapping the outcrops north of the Giri river, I had not seen the Mandhalis. The sections showed that a series of thin-bedded limestones and dark slates, with some soft green slates, passed up to the Bansa limestone and then into Jaunsars of Nagthat type. Boulder beds were found sporadically at the

base of the succession. The occurrence of limestones did not seem anomalous, since they had been seen elsewhere in the Jaunsars, and accordingly the whole sequence was regarded as Jaunsar. The boulder beds were mapped as Blaini, and were considered to have been thrust over by the Jaunsars. Later, on acquaintance with the Mandhalis, it was realised that the beds low down in the sections were probably Mandhali. To what extent the boulder beds in the eastern part of sheet 53 J/10 are Mandhali, and to what extent Blaini, is altogether uncertain since at that time, I had not learnt to know the features which differentiate these boulder beds. An attempt has been made to mark the approximate extent of the Mandhalis by stippling. A definite boundary with the Jaunsars cannot be drawn.

In the neighbourhood of Dadahu, a complex association of Infra-Krol slates and Blaini boulder beds has been overthrust by the Jaunsars and Mandhalis. Bleaching slates of Infra-Krol type occur also in the Mandhalis, and it may be objected that, near Dadahu, Mandhali slates and boulder beds have been mistaken for Infra-Krol and Blaini. The beds mapped as Infra-Krol are overlain by Krol limestones on hill 3,619 feet, and continue to the north-west for 40 miles along the strike, always overlain by Krol limestones, and always associated with Blaini boulder beds and limestone. It is not likely therefore that they have been incorrectly mapped near Dadahu. Uncertainty only exists between Dadahu and the Tons river, because there slates and boulder beds occur, without Krol limestone, that might be either Mandhali or Blaini and Infra-Krol. This, in my opinion, is no proof that the Blaini, Infra-Krol and Mandhali are the same. It is simply an illustration of the complexity that may arise when similar rock types, whether contemporaneous or of different ages, are brought together by thrusting and unconformable overlap.

One other exposure, at the north-western end of the Krol Belt, may be mentioned. This is an isolated lenticular outcrop of folded and brecciated limestones, together with knotted slate, which occurs at Dhari, near Kandaghat. It was at first regarded rather doubtfully as Krol A, on account of the lenticular folded blue limestones. Since the rocks occur wedged in between Jaunsars and Simla slates, and the limestones are more similar to those of the Mandhalis than to the Krol A limestones, the outcrop may with confidence be mapped as Mandhali.

The limestones at Badgala are of the same type, folded and brecciated.

## Conclusions.

The argument relating to the position of the Mandhali rocks is based on the following points :—

(1) In south Chakrata, a thick series of Mandhali rocks appears to pass normally upwards into the Chandpur stage of the Jaunsar series. No trace of a thrust plane is seen. The boundary chosen between the two stages is one of convenience, *viz.*, at the top of the Bansa limestone.

The undoubted Blaini, on the other hand, which in this region consists solely of a boulder bed and an overlying pink siliceous limestone, passes up into the Infra-Krol : Krol : Tal succession, which is the type succession for the Krol Belt.

(2) In the Kandaghat area, Simla slates appear to grade upwards into Jaunsars. Boulder beds and pink limestone sometimes intervene, which admittedly are identical to those in the Blaini. At Dhari, near Kandaghat, occur brecciated limestones, of Mandhali type, between the Jaunsars and the Simla slates, so that the parallel with Chakrata area is moderately close.

(3) Boulder beds definitely occur in the Nagthat rocks that are quite distinct from the Blaini. The occurrence of other boulder beds, in the Mandhalis, need not therefore occasion surprise and lead to the deduction that they must inevitably be Blaini. This is supported by occurrences of boulder beds at more than one horizon both to the north-west and to the south-east of the Krol Belt. Boulder beds are not rare in the Himalaya, either in space or in time. Their manner of origin is not everywhere the same. It cannot be argued that in the Simla area similarity implies contemporaneity or even identity in manner of origin.

It was stated on page 397, that the Blaini between Simla and Badgala may in reality be Mandhali. The conclusions reached here may somewhat simplify the structure of the Simla-Chakrata area, since they would eliminate the necessity of a thrust at the base of the Jaunsars.

Mr. West has found the Mandhalis of northern Chakrata to grade downwards into Deoban limestone, fragments of which they contain.[1] This same Deoban limestone rests on the Jaunsar series, while, in the Beshair and Gutu Gads, Jaunsars are found as well above the Deoban limestone.

The occurrence of Deoban limestone normally below the Mandhalis does not affect the argument given above, because the Mandhalis south of Chakrata are probably thrust over the Morar-Chakrata

[1] *Rec. Geol. Surv. Ind.*, LXVI, pp. 128-129, (1932).

beds (Simla slates). If the interpretation given in this paper be correct, the position of Jaunsars below the Deoban limestone must be due to a thrust.

## X. CORRELATION WITH MUSSOORIE AND GARHWAL.

In 1933, mapping was continued eastwards, past Mussoorie. In July and October, 1932, short visits were paid to Lachmanjhula and Lansdowne in British Garhwal. The Garhwal area was mapped by Middlemiss in 1885-1887.[1]

### Mussoorie (Sheet 53 J/3).

The Blaini: Infra-Krol: Krol: Tal sequence reappears south-east of the Jumna river and has been traced eastwards to longitude 78° 15′. The series of this sequence occur in synclinal form, with the axis of the syncline running N. W.–S. E. just north of Landour cantonment. On the north side of the syncline, the Blaini rests on the Nagthat stage of the Jaunsar series. The south side has not been examined in detail, but it evidently presents the same difficulties, on account of unconformable overlap and extensive thrusting, as have been experienced along the Giri river.

The series of this sequence are typically developed and are unmistakable. Upper Krol limestones make up the whole of the Mussoorie ridge from Banog to the Landour bazar. Krol E limestone is well seen just opposite Stiffles' cocktail bar. Landour cantonment is built on lower and upper Tal rocks, which extend along the Mussoorie-Tehri mule-track as far as mile 5.

A distance of 18 miles still remains in order to join up with the mapping of Middlemiss. That the rocks of this sequence will continue into Garhwal is evident from the brief traverses made at Lachmanjhula and Lansdowne.

### Lachmanjhula (Sheet 53 J/S. W.).

The area between Lachmanjhula and Bijni is not favourable for seeing outcrops, owing to thick jungle. Between Lachmanjhula and mile 18 (on the Hardwar-Badrinath pilgrim track), there are black, carbonaceous, slaty shales and silty limestones, similar to the combined Krol A, Infra-Krol rocks east of Dadahu. By mile 18

[1] *Rec. Geol. Surv. Ind.*, XX, p. 33, (1887).

occur banded, green, calcareous slates, very characteristic of the Krol A stage. Along the pilgrim route near mile 19, and on the path from Lachmanjhula to Bhadsi (30° 06′ : 78° 21′), between aneroid heights 1,900 and 2,500 feet, there are seen red shales identical to these in the Krol B, Red Shale, stage. Massive, cream-white, 'pseudocoralline' limestones occur in the stream three-quarters of a mile up from Gattugad Chatti (30° 05′ : 78° 23′). These are identical to the Krol E limestones (specimen 43·766) found in the ravine one-third of a mile E. S. E. of hill 5,930 feet (30° 43′ : 77° 17′).

The Massive Limestone is followed upwards near Kota (30° 07′ : 78° 25′) by well-bedded white quartzites, which cross the Ganges, and occur as dip slopes by Atali (30° 04′ : 77° 28′). They are exactly like the Upper Tals of Mussoorie and the area west of the Tons. The equivalent of the Lower Tals in Garhwal appears to be in the carbonaceous shales and sandstones seen at the confluence of the Huinl and Ganges rivers. The white quartzites of the Upper Tals are much thinner near Bhadsi, where they grade upwards into dark, current-bedded calc-sandstones or sandy limestones, sometimes oolitic, and generally crowded with broken fossils.

## Medi Gad, near Lansdowne (Sheet 53 K/N.E.).

Exposures may be seen in the Medi Gad, from Raitpur (29° 54′ : 78° 42′) to near the Eastern Nayar river. The Tal beds do not show up well. Below them comes a blue, crystalline, massive limestone exactly like the Krol C. By a small stream half a mile E. N. E. of Raitpur, the massive limestones are followed below by red sheared shales, with blotches of green and occasional dolomitic limestone bands, identical to those in the Krol B stage. Going down the dip come successively :—lenticular dark limestones set in calc-slate, and banded grey and green slates (Krol A), black, banded, carbonaceous slates with salty efflorescences (Infra-Krol), purple mica-slates with subordinate green slate bands, thin limestones; a thin conglomeratic breccia, purple slates, and finally ripple-marked quartzites, strongly veined with quartz. Since Middlemiss draws his boundary between the Massive Limestone and the Purple Slate series exactly at the above-mentioned stream, it is clear that he regarded the red shales and green calcareous slates as part of his Purple Slate series. A suspicion that this was so was

aroused near Lachmanjhula, but the thick jungle there and the intense July heat prevented any detailed examination. In this manner of division, Middlemiss was perfectly justified. The thin calcareous slates (Krol A) of Garhwal clearly have very little in common with the cliff-forming Massive Limestone. Being slates, they would naturally be classed with the Purple Slate series, the more so since red shales occurred above them. This is in contrast to the Solon neighbourhood, where the thin-bedded Krol A limestones occur in cliffs 300 feet high. The change that has taken place in the 120 miles that intervene between Solon and Raitpur, is due more to change in composition than to any demonstrable increase in intensity of stress in the Garhwal area.

The purple slates may belong partly to the Infra-Krol and partly to the Jaunsars. The ripple-marked quartzites, low down in the Medi Gad section, are exactly like those found in the Jaunsars of the Simla-Chakrata area. If this be so, the 'volcanic breccia' of Middlemiss must occur below the Jaunsars, in just the position of the Mandhalis.

## Sutlej River Area (Sheet 53 A.).

At the opposite end of the Krol Belt there is a narrow strip of limestone which crops out amongst the Tertiary rocks from Badhota (31° 03′ : 76° 55′) northwards to the Sutlej river, north-east of Bilaspur (31° 20′ : 76° 45′). Good exposures of cherty limestones and interbedded red and black shales of Krol D type may be seen on the path from Bilaspur to Parnali (31° 18′ : 76° 47′). These limestones were noticed by Medlicott[1] and by Pilgrim.[2] Both writers regarded them as Krol.

## Conclusions and Table of Correlation.

Adopting the correlation of the Upper Krol limestone with the Massive Limestone of Garhwal, the Krol rocks are seen to extend from the Sutlej river, near Bilaspur, to Gungti Hill (29° 45′ : 78° 55′) in Garhwal, a distance of some 175 miles. The limestones

[1] *Mem. Geol. Surv. Ind.*, III, p. 80, (1864).
[2] Field Diary for March, 1924 (not published).

at Naini Tal are most probably Krol, which would bring the total length of outcrop up to 208 miles.[1]

The following table is offered as a tentative correlation. The correlation with the Kashmir-Hazara area is partly drawn from information supplied by Wadia and West, in the Director's General Report for 1930.[2] It must be regarded as very tentative.

*Correlation Table.*

| | Hazara-Kashmir. | Simla-Chakrata. | British Garhwal. |
|---|---|---|---|
| Oligocene.<br>Eocene | Nummulitics | Subathus | Nummulitics. |
| Cretaceous | Giumal sandstone | Upper Tal | Tal. |
| Jurassic | Spiti shales | Lower Tal | Almost absent. |
| Trias | Trias limestone | ? Absent | ? Absent. |
| Permo-Carboniferous. | Infra-Trias limestone and Panjal trap. | Krol E<br>Krol D<br>Krol C } Upper Krol limestone. | Massive Limestone. |
| | Upper Tanawal (Tanol) | Krol B Red Shales<br>Krol A Lower Krol limestone. | Purple Slates (with occasional boulder beds). |
| Upper Carboniferous | Agglomeratic Slate<br>Talhatta conglomerate | Infra-Krol<br>Blaini | |
| ? Devonian and Silurian. | Lower Tanawal (Tanol)<br>Conglomeratic boulder bed | Nagthat stage<br>Chandpur stage | Volcanic Breccia. |
| Lower Palaeozoic and pre-Cambrian. | | Mandhali stage | |
| | Dogra slates | Simla slates——?—— | ——Schistose series. |

Dolerites have been found intrusive into Krol and older rocks and into Tertiaries, but not in Tals. There is possibly a Permian-Krol suite and a later Tertiary suite.

[1] It was stated in *Mem. Geol. Surv. Ind.*, LIII, p. 8, (1928), that the Krol limestone extends to the north-west as far as the Ravi river. This must be an accidental error, occasioned by the title of Medlicott's memoir. Between Bilaspur and the Ravi river, the rocks bordering the Tertiaries are older than Krol. At Joginder Nagar (32° 0′ : 76° 47′), schists, phyllites and quartzites, together with intrusive porphyritic granite, are thrust over the Tertiaries. These are either Jutogh, Chail or Jaunsar. The Krol limestones are definitely absent. The equivalent of the Krol rocks is probably not seen until Kashmir is reached.

[2] *Rec. Geol. Surv. Ind.*, LXV, p. 128, (1931).

## XI. TECTONICS.

The most cursory examination of the rocks of the Krol Belt shows their extreme complexity of structure. This complexity is seen in single exposures as well as in broad views. It becomes evident as a result of continued mapping, and may be seen at a glance in a rock-slice.

In places there is such chaos that no rational explanation is possible. Objection may be made to the adjective 'rational'. It may be maintained that with fuller knowledge, or with better exposures in the jungle-covered lower slopes of the hills, the chaos might prove to be apparent, and might resolve itself into structures more readily explicable. To some extent this objection must always hold, but it is less readily applied in describing orogenic areas of the type seen in the Krol Belt. Structure is everywhere seen by eye to be so chaotically disposed that the fear is that the map, however odd, does not adequately show it. For certain tracts bordering the thrust-planes, the only 'rational' explanation is one that does not attempt to simplify at the expense of structure, in favour of readily understandable sections. Such tracts are, therefore, difficult to represent on the map, partly because the scale demands simplification, partly because of an inherent dislike of leaving suspicious loose ends and oddly juxtaposed colours.

No thrusts or faults have been marked on the one-inch maps, since almost every plane separating rocks of different hardness, and every boundary plane between different stages, is a minor or major thrust. The major features have been traced on a separate quarter-inch map, Plate 24. It is these alone that can be here described.

### Thrust-bound Synclines.

Broadly speaking, the structure of the Krol Belt is that of two thrust-bound synclines of Krol (in the east, of Krol and Tal) rocks resting on a Jaunsar-Simla slate foundation.

(1) The *Nigali* syncline, named after the magnificent ridge that runs south from near Guma peak. Tal and Krol rocks occur in a wide syncline, with steep northern limb, locally inverted and severed by the Guma thrust. The southern limb is attenuated and founded on the Giri thrust.

(2) The *Krol Hill-Kamli Dhar* syncline. This is more complex, being built up of minor synclines and anticlines, often disposing the Krol lime-

stones in outliers. The following chief individual units are recognisable, in order from north-west to south-east :—

(*a*) Pachmunda and Krol synclines.
(*b*) Khanog and Rajgarh synclines.
(*c*) Narag-Dadahu stretch of continuous Krol limestones.
(*d*) Kamli Dhar and hill 3,619 feet synclines.
(*e*) The easterly continuation of the Kamli Dhar syncline with enclosed Tal rocks; the Korgai syncline.

This complex of synclines is bounded on the north-east by the Giri thrusts, and on the south-west by the Krol thrust.

The two main dislocations along the belt are the Krol and Giri thrusts. The Giri thrust has caused the most havoc, since the hard foundation of Jaunsar and Simla slates has been pushed upon incompetent Krol limestones. It has produced a series of minor thrusts and inversions in the Krol rocks, which are best seen on the northern face of Krol Hill. The thrusts are generally parallel to the limbs of the folds, *i.e.*, parallel to the bedding-planes of the beds making up these limbs.

The folds do not call for much comment. The Kamli Dhar syncline is markedly inverted through 120°, Krol B, Krol A and Infra-Krol all dipping to the north in inverted sequence. A singular feature of the Krol belt is the nature of the folding within the Krol D stage. The limestone bands twist and overfold amongst shales in an intricate manner, as may be seen in section No. III on Plate 25.

It should be pointed out that the irregular folding of the Krol and Infra-Krol rocks is due to their incompetent nature, and cannot be considered a feature of primary structural significance, peculiar to the particular zone of rocks that intervenes between the belt of Tertiary rocks to the south-west and the phyllite-schist zone to the north-east. The rocks concerned had not been stiffened up by any previous metamorphism at the time of the Tertiary orogenics, and the rapid alternations of limestone and shale would naturally permit intricacy of folding. The major features are thrust-sheets, just as is so in the schist zone to the north-east.

## Krol Thrust.

The Krol thrust is the 'Main Boundary fault' of earlier writers who have described analogous areas.[1] From Solon to Dadahu it

[1] Middlemiss, *Mem. Geol. Surv. Ind.*, XXIV, pp. 19, 31, etc. (1890).

brings Infra-Krol and Blaini rocks against Subathu, Dagshai and Kasauli stages. Further east, Blaini, Jaunsar and Mandhali rocks override Subathus and eventually come to lie upon Nahans. It marks the approximate boundary between Krol and their foundation rocks (*Himalayan* of Medlicott) and the main belt of Tertiaries (*sub-Himalayan* of Medlicott).

**Medlicott.**

Medlicott did not map this boundary as a fault, since he believed that it represented the slightly disturbed cliff face that originally formed a boundary to the deposition of nummulitics, and against which the Nummulitics, Dagshais and Kasaulis were banked. In describing the area immediately to the south of Subathu [1], he stated that the junction between the Subathu and pre-Tertiary rocks, although giving the impression of a great fault line, was in reality undisturbed, the relative position of the beds in contact on the Boj (modern *Pachmunda*) being what they originally were. This view is certainly untenable, since, apart from any question of the Subathu–Infra-Krol boundary, the Subathus themselves occur faulted against Dagshais and Kasaulis. In considering the nature of the boundary, it must be remembered that Medlicott consistently believed that not only the one with which we are directly concerned, but also other boundaries, such as that between the Middle and Upper Siwaliks, in the Markunda *nala* south of Nahan, were tilted cliff faces. Thus on pages 107 and 108, he describes the superposition of Middle Siwaliks on Upper Siwaliks, stating that older observers regarded the sequence as natural. He was aware that similar puzzling sections had been found in the Alps, and of the usual assumption of 'prodigious faulting' to account for this abnormal superposition. Nevertheless, he finishes up by believing that the section was an original contact and that '*no fault at all has occurred*'. Similarly, on pages 115 and 116, he dismisses the northward dip of Nahans below pre-Tertiary rocks, near Mussoorie, as '*quam proxime*, an original one'. Medlicott is a difficult writer, whose arguments are not easy to follow, but it is clear that his whole position depended on this idea of slightly disturbed contacts of old vertical cliff walls against which the Tertiary rocks were successively banked. Below Mussoorie, these old cliffs must have been 10,000 feet high, because it is the upper part of the Nahans that is

[1] *Op. cit.* III, Pt. 2, pp. 83, 84, (1864).

juxtaposed against pre-Tertiaries, and, by hypothesis, the Subathus, Dagshais, Kasaulis, and Lower Nahans must all have been previously banked up against this wall, only to be covered up with the higher Nahans now actually seen. It cannot be supposed that the Nahans had overlapped beyond the Subathus in a north-easterly direction, and therefore be argued that the cliffs need not have been so high, because it is known that Subathus occur in this direction in places where the Nahans have never been found.

I have seen the sections both south of Nahan and below Mussoorie. To my mind, there is no alternative explanation to that of the existence of thrust planes. The thrust below Mussoorie is the continuation of the Krol thrust.

**Dhaduwala section.**

The sections in the Makunda *nala* south of Nahan, near Dhaduwala village, show gently dipping Upper Siwalik conglomerates, overlain by highly coloured Middle Siwalik 'Nurpur' sand-rock and clays. These clays are very soft. It is not likely that they would ever have formed a steep cliff. They do indeed form a cliff at the present day, but one that is marked out by terraces of earth pillars and highly crumbled sand-rock. Most certainly this sand-rock would have been incorporated in the Upper Siwalik sediments, had these been deposited, as was supposed, against it. No sign of the sand-rock is actually found. The pebbles in the Upper Siwaliks of this locality are solely those derived from the Lower Siwalik or Nahan sandstones. Neither do the Upper Siwalik rocks show the bright colours of the Nurpur beds.

The present junction between Middle Siwaliks and underlying Upper Siwaliks is a plane that dips northwards at angles of less than 45°. It is sometimes parallel, sometimes slightly inclined, to the bedding planes of the Upper Siwaliks. If this junction had once been vertical, but was later tilted over towards the south, as depicted by Medlicott in Figs. 14 and 15 of his memoir, it would be expected that, in proportion as the cliff face assumed parallelism with the beds that were originally deposited at right angles against it, so must there have been faulting. Medlicott himself speaks of 'boundless tangential forces' (page 110) and yet was unwilling to allow even limited reverse faulting to account for this contact, remarking that it was a relief to find an escape from the usual modes of accounting for such juxtapositions. It would be quite wrong to throw aside Medlicott's ingenious suggestion as being without value, but

it is clear that he exceeded its legitimate application in regard to the Krol thrust, and even to the thrust seen at Dhaduwala.

Medlicott also thought that Nummulitics did not occur to the north-east of the area where he had noticed them, a belief that was connected with his idea of cliff barriers. Later, Middlemiss found Nummulitics on the Tal rocks of Garhwal, and recently I have seen them on Krol limestones (page 403), and at Dabra, north of the Tons thrust. In all these cases they are often seen at higher altitudes than the Nahans found south-west of the boundary fault, and imply an elevation equivalent to their position in the geological succession below the Nahans, plus the height difference now seen. Some of this elevation of Nummulitics is, of course, due to folding, but the folds have only a fraction of the amplitude that would be required to bring the Nummulitics to the height above the Nahans at which they now occur. The sliding of a whole zone of rocks over a thrust-plane would readily account for this position.

**Recent survey.**

The recent survey of the Krol Belt has established conclusively the thrust condition of the contact between the pre-Tertiary and Tertiary rocks, though doubt is still left as to the importance of the thrust in the neighbourhood of Solon. Thrusts in that area are certain, but whether the Krol limestones of Pachmunda Hill form an outlier resting on an extensively thrust and folded *nappe* is not definitely proved.

The most convincing places for demonstrating the low angle of contact of pre-Tertiary rocks, with underlying Tertiaries, are the following :—

(*a*) In the Amlawa and Tons rivers, near Kalsi, where Mandhalis rest gently upon hardened red shales that are either Dagshai, Nahan or Middle Siwalik.[1] The dip of the thrust varies from 25° to 35°, northwards.

(*b*) Mapping shows the low angle of contact between the Infra-Krols and the Subathus between hill 4,217 feet and Dadahu.

(*c*) Between height 3,241 feet on the Kawal Khal river and hill 4,633 feet Infra-Krol and Blaini upon Subathus.

(*d*) Between the Blaini river and Bharech col, Infra-Krol and Blaini upon Subathus.

[1] Pilgrim, *Mem. Geol. Surv. Ind.*, LIII, p. 50 (1928), regarded these shales as Dagshai. They were taken by Oldham to be Nahan. They appear to me to be either Nahan or Middle Siwalik, being unlike the Dagshais of the type area. It is true that the shales are crushed and hardened, under the Krol thrust, so that resemblances may have been rather obscured, but I cannot see that Dr. Pilgrim could have had 'no hesitation' in regarding them as Dagshai. The question is immaterial to the matter discussed above. In the map I have coloured them as Nahan.

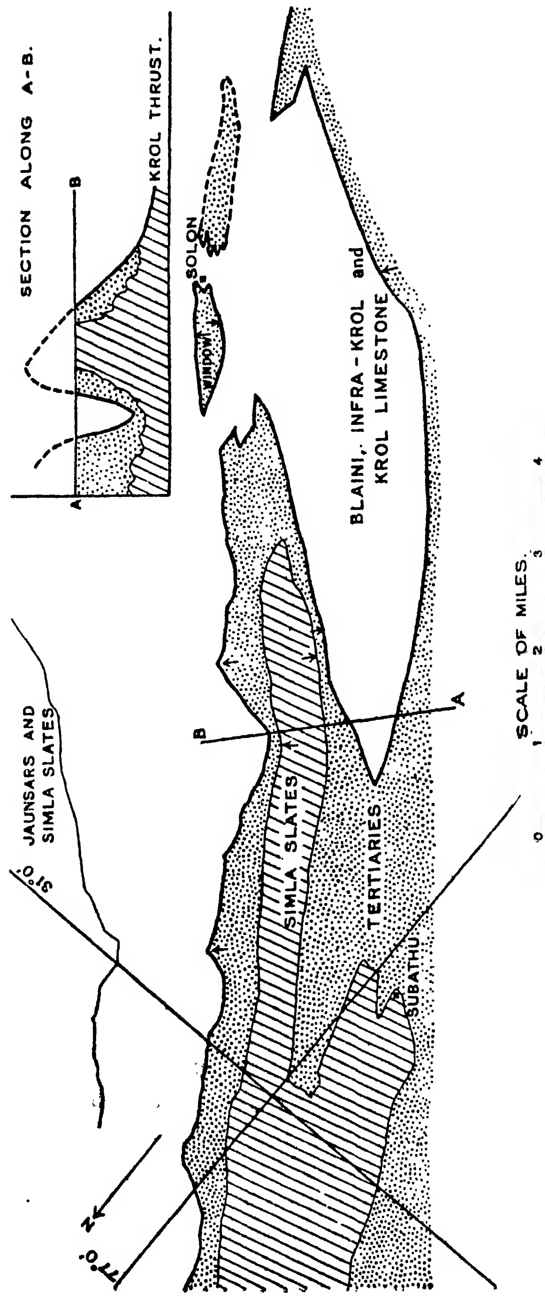
The thrust is not everywhere of the same gentle hade. North-west of Barog railway station it is even inverted for a short distance, between the motor road and the 5,800 feet contour, hading south-west. For most of the way between Narag and Dadahu, it has a very steep hade to the north-east.

The interpretation of the structure round Solon is one of great difficulty. It will be seen from the map that there is a narrow outcrop of Subathu rocks running up the Blaini river towards Solon, which is flanked by Infra-Krol rocks, and which itself has a core of Simla slates. The relations are shown diagrammatically in Fig. 1 on page 436. The Tertiaries are found to dip, both at steep and at gentle angles, beneath the Blaini, Infra-Krol and Krol limestones. They are known to rest at Subathu upon Simla slates. Across the Blaini valley there is the apparent succession.

Blaini, Infra-Krol and Krol limestones.
. . . . . . . . . . .(*Krol thrust, inferred*).
Subathus.
. . . . . . . . . . .(*normal superposition*).
Simla slates.

It is difficult to suppose that the Subathu rocks had been caught in two parallel and strongly pinched synclines amongst older rocks, because, if this were so, the enclosing older rocks of both limbs of the synclines should be the same. In reality, Simla slates are found in the middle of the Subathus, while Blaini–Infra-Krol flank them on either side. The apparent structure is that of a single anticline pitching to the south-east, with the sequence given above. Only by a curious accident could the Subathus have been deposited in a bay, bounded by cliffs of Blaini–Infra-Krol (now represented by Krol and Pachmunda Hills), and with a floor of Simla slates. Under these circumstances it would be possible to imagine that subsequent movement might fold the cliffs of Blaini–Infra-Krol over Subathus, and at the same time, elevate the floor of Simla slates. This is the view that Medlicott adopted. It implies that overfolding of the cliffs was negligible near Solon, but great to the north-west. It implies also that the cliffs at Pachmunda were folded on the south-west side over to the south-west, and on the north-east side over to the north-east.

There is no doubt about the normal unconformable superposition of Subathus on Simla slates. If the Blaini–Infra-Krol, with outliers of Krol limestone, are found to occur above Subathus, the




Arrows show general dip of contact. ——--Trace of inferred thrust-plane.

FIG. 1.—Diagram showing structural relationships north-west of Solon.

alternative inference may be made that their position is due to thrust faulting, subsequent folding of which has led to the formation of the Pachmunda outlier and has exposed the underlying Subathus in a pitching anticline along the Blaini river and in two *windows* near Solon. The magnitude of translation, on this inference, is great, too great probably for those who look only at the Subathu/Infra-Krol contact near Barog station.

It can hardly be doubted that the Subathu/Blaini/Infra-Krol contact, north-east of the narrow outcrop of Simla slates, is a thrust. The curved nature of the outcrop of the dividing plane, with the V pointing north-east, into the valleys, shows that the plane is gently inclined. Further, the width of the Subathus between the Blaini–Infra-Krol and the Simla slates is very variable, expanding with depth. Neither can it be doubted that the contact seen south-east of Solon, between hill 4,633 feet and height 3,241 feet in the Kawal Khal, is also the trace of a thrust-plane.

It may be held, however, that these two thrusts join up near Solon, and do not swing round Pachmunda Hill, as is here supposed. Support for the objection could be found in the occurrence of the Subathu pisolite near hill 4,819 feet, immediately below the Blaini–Infra-Krol, from which it could be argued that the magnitude of translation could not be great if the original bottom bed of the Subathus is still preserved. This bottom bed also occurs in the Kawal Khal, where there is every reason to believe the thrust to be important. Its occurrence near the 4,819 feet thrust-contact could be regarded as fortuitous.

The issue is, in some respects, similar to the controversy concerning the Glarner fold in the Alps, which was at first interpreted as a double 'mushroom' fold, but was later considered to be a *nappe*-fold, based on a thrust-plane. I see no evidence apart from boring which will settle the question, but the explanation offered of a folded thrust-plane of great extent seems reasonable, bearing in mind the magnitude of the extensive thrusts known to exist along the Himalayan foothills.

Some indication that the Krol thrust is more than a minor feature is given by the fact that it overlaps the Nahan thrust (which separates Subathus from underlying Nahans) in an easterly direction. At

Nahan, the Nahan thrust is five miles distant from the Krol thrust. At Sataun it disappears, together with the Subathu rocks, and pre-Tertiaries rest directly on Nahans.

One of the most noticeable features of the Krol Belt is the change in strike near Dadahu from N. W.–S. E. to nearly east and west. Similarly, between the 31° and 32° latitudes, north of the area described in this report, the strike changes from N. W.–S. E. to nearly due north and south. A careful following of the boundaries between the stages in the Tertiaries might disclose the fact that the Krol thrust, and other thrusts separating the Tertiaries from the pre-Tertiaries, have caused an extensive tectonic overlap of older rocks upon younger, over a distance dependent on the amount of departure of the outcrop of the dividing plane from N. W.–S. E. My own observations amongst the Tertiary rocks were not extensive enough to prove the point.

The actual fold-axes in the Tertiaries appear to follow the same general change in strike that is shown by the Krol Belt, since the folds probably arose as a result of pressures initiated by the foreward movement of the belt over the Krol thrust. But a detailed examination of the fold-axes of the boundary planes between the folded stages, may well show that these are truncated by the Krol and analogous thrusts.

## Giri Thrust.

The Giri thrust is a well-marked feature which has been traced from the Gambhar river to north-east of Chandni, where it dies out in an anticlinal fold.

It was noticed by Medlicott, who has shown a part of it very accurately.

North-west of Kandaghat, the thrust is steep and separates Simla slates from Jaunsars. Along the Ashmi river, its dip becomes gentler. Simla slates are thrust first over Infra-Krol, and then over themselves. The thrust has not been traced between Sunnu and Gauhra, but is seen in the Giri river below the Gauhra Rest House, where two facies of the Simla slates are separated with disturbance by an inclined fault. Further south-east, the thrust truncates an anticline of Blaini with underlying Chhaosa, beds

belonging to the Simla slates, in the manner shown in the diagrammatic section below.

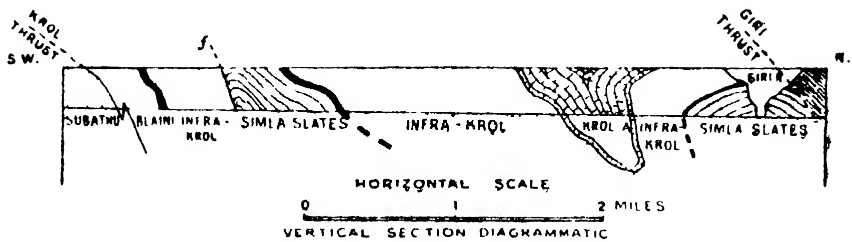



FIG. 2.—Diagrammatic section along Kawal Khal river (Blaini shown in black). Horizontal scale, 1 inch = 1 mile. Vertical section diagrammatic.

This is a modification of the sections given on pages 12 and 13 in *Mem. Geol. Surv. Ind.*, LIII, (1928). The Giri fault there marked is now regarded as a major feature, and its position has been changed from the south-west to the north-east limb of the anticline of Simla slates that runs along the Giri river. If the Blaini of Dudham should prove to be Mandhali, and if the Mandhalis occur normally between the Jaunsar and Simla series, there would be no need to postulate the Jaunsar thrust. The section above the Giri thrust would be a normal one.

Mapping is very difficult from height 2,820 feet down to Niwar, though the existence of thrusts is definite. Below Bongli, Jaunsars dip at 60° to the north-east upon Krol C. Two miles to the south-east the thrust is inverted, dips being to the south-west. At Milan, imbricated Jaunsars and Blaini again dip to the north-east at 40°-50° upon Krol C limestone. Eastwards the dip of the thrust varies. North-west of Kando, uninverted Jaunsars rest at a low angle on inverted Blaini. In the Nait ka khala, the Blaini is cut out, and Jaunsars overlie an inverted succession of Infra-Krol and Krol limestones. The Giri thrust then splits up into several minor, parallel, thrusts, which eventually die out in the Barbas anticline.

## Tons Thrust.

The Tons thrust is a fairly well-marked feature which separates Mandhalis and Jaunsars from the underlying Moiar-Chakrata beds. By height 2,206 feet, on the Tons river. Jaunsar rocks occur in the 6,000-foot scarp on the right bank, dipping south-west, while on the

left bank occurs the Deoban limestone, dipping apparently to the north-east in cliffs and terraces nearly 7,000 feet in height. A great dislocation is therefore required to explain the juxtaposition of unlike rocks on the two sides of the Tons river.

In connection with the present discussion, the important point is that the Tons thrust dips to the south-west and south. Since the Krol thrust dips northwards, it is possible that the two thrusts are the same, and that the great syncline of Jaunsar rocks, with overlying Krols and Tals, rests as a *nappe* on a folded thrust-plane. Should this be so, the Krol thrust would be of premier importance in the structure of the area. No information is to hand to prove the point.

Below the Tons thrust occur Simla slates, together with soft purple sandstones of Dagshai [1] type and Nummulitic beds. Definite Nummulitic limestones, associated with vitreous quartzites and green shales, are seen at Dabra. It is very probable that the lenticular limestones, shattered white quartzites and green shales that crop out between the 3,500- and 3,250-foot contours on the path from Sarog to Sayasu, are also Nummulitics.

To what extent the purple sandstones are Tertiary is impossible to determine. At Kailana and along the Seli Gad to the east, mottled purple sandstones occur interbedded with the concretionary facies so typical of the Chhaosa type of the Simla slates and may reasonably be considered to belong to the Simla slates. Moreover, Dagshai-like sandstones occur as boulders in the Blaini, boulder bed, which is without question pre-Tertiary, and is with fair certainty pre-Mesozoic, thereby proving that there must be at least two series of sandstones of similar type, one pre-Mesozoic, the other Tertiary. It does not follow that all these sandstones north of the Tons thrust must belong to the Simla slates, but only that they cannot all be Dagshai.

This occurrence of Nummulitics below both the Krol and the Tons thrusts is suggestive of the possibility that they are continuous beneath these thrusts. The centripetal disposition of Nummulitics below the Inner Schistose series of Garhwal may be recalled.[2] It is true that Middlemiss did not favour the idea, which he himself brought forward, that the Inner Schistose series occurred as a *Klippe* upon continuously underlying Nummulitics, but a

[1] *See Mem. Geol. Surv. Ind.*, LIII, p. 38, (1928).
[2] *Rec. Geol. Surv. Ind.*, XX, pp. 34, 36, (1887).

re-examination of the Garhwal area may eventually establish that this is so.[1]

The question of the identity of the Krol and Tons thrusts has yet to be settled, but it seems reasonable, in view of the similar tectonic sequences on either side of the Jaunsar syncline, to regard them as one and the same thrust that has been subsequently folded.

## Small-scale Structures.

It is unnecessary to describe in detail the varied reactions of different rock facies to stress. The following five sketches, all drawn from photographs, will give a fair indication of the complexity that prevails. Reference should also be made to Plate 21, fig. 1, and to Plate 22.

The Subathus, the Krol B and D stages and the Infra-Krol have suffered the most disturbance. The complexity of folding

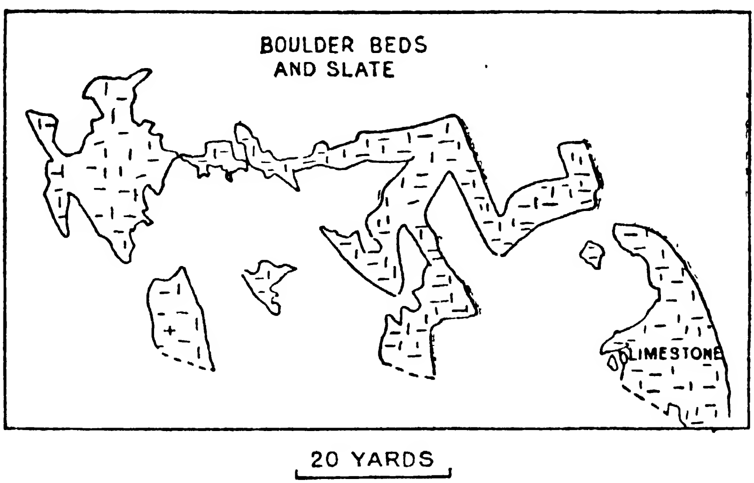



FIG. 3.—Interdigitation of Blaini limestone in boulder beds and slates, left bank of the Jagar ka Khala, near confluence with Giri. river.

[1] Middlemiss was aware in 1887 of the thrust structures that were at that time being discovered in the North-West Highlands of Scotland, but he considered that the Garhwal area, examined on its own merits, did not warrant similar deductions. It is possible that the great *nappe* structures found in the Alps predispose geologists to find them elsewhere in analogous orogenic belts. Even allowing, however, for such a predisposition, and for an unconscious neglect of facts that might negative explanation of structure by *nappe* formaton, the undeniable existence of such structures in many mountain-chains makes it probable that another interpretation may be put on the structures present in Garhwal.

and fracture shown by such soft rocks when caught up in orogenic movements, is greater than that of the older, more indurated rocks. Rocks previously converted into quartzites, slates and clay-slates will already have attained a certain degree of stability and competence before the oncome of the Tertiary orogenics. These competent beds would act as structures capable of resolving the Tertiary stresses into definite directions. This is not so with the Subathus, in the soft sandstones and shales of which adjustment to strain has been irregular and without orientation (see Figs. 4 and 5).

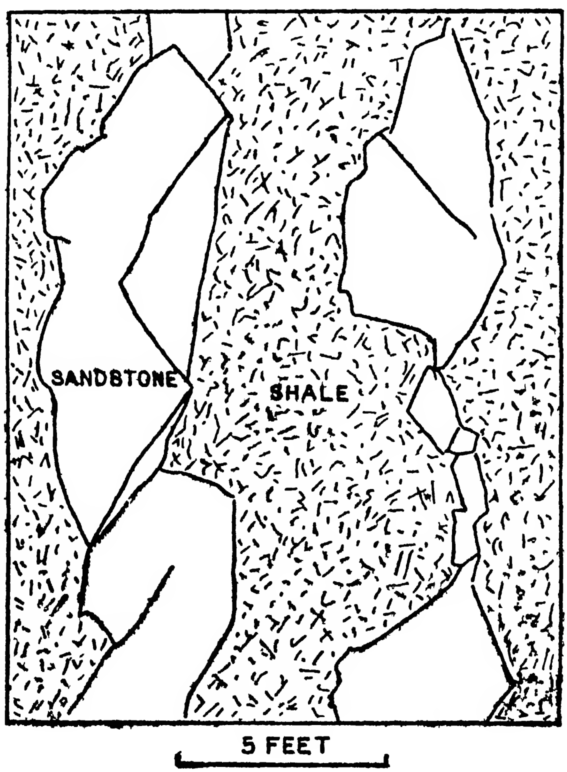



FIG. 4.—Attenuated beds of sandstone in shale, Subathu stage, Gambhar river, one mile east of Haripur.

Induration is not the sole factor. The shales and sandstones of the Dagshais are no more indurated than those of the Subathus, but yet the Dagshais are folded in a much simpler and more regular

manner. Further, the shales and limestones of the Krol D stage in the east of the area are less contorted than those of the same stage near Mangarh. This may be explained by the fact that the

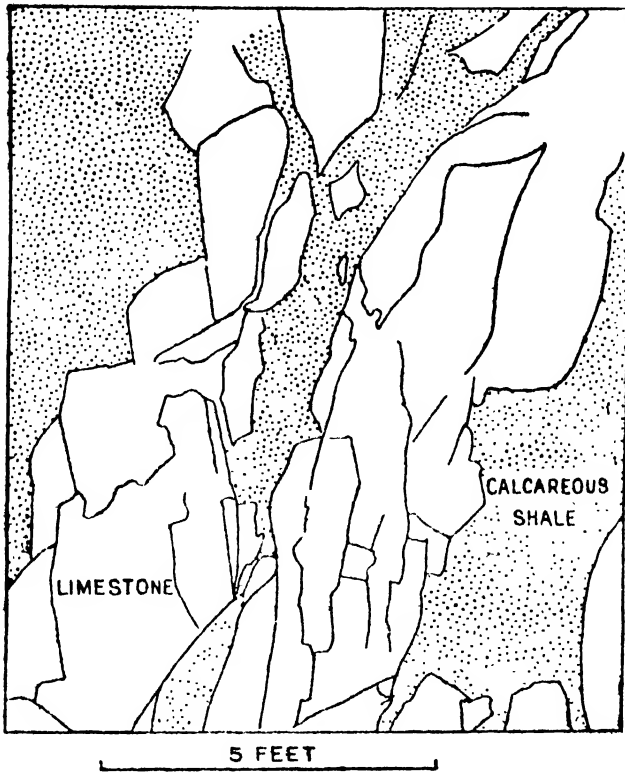



FIG. 5.—Shattered beds of limestone in calcareous shale, Subathu stage, left bank of Koshallia *nadi*, two miles E. S. E. of Kalka railway station.

very regular alternations of *equal* thickness of sandstone and shale in the Dagshais, and of limestone and shale in the eastern development of the Krol D stage, tend to prevent unequal redistribution of material. Other factors, such as the protective influence of the Tal beds on the underlying Krol rocks, are also of importance.

The complexity of miniature folds and thrusts in the Mandhali limestones (Fig. 6 on page 444) is due to the original lenticular habit of the limestone and phyllite, by which the many discontinuous beds of limestone would each tend to fold individually within the more

general phyllitic matrix. It may be presumed that the greater angularity of folding and fracture of the Mandhali limestones in

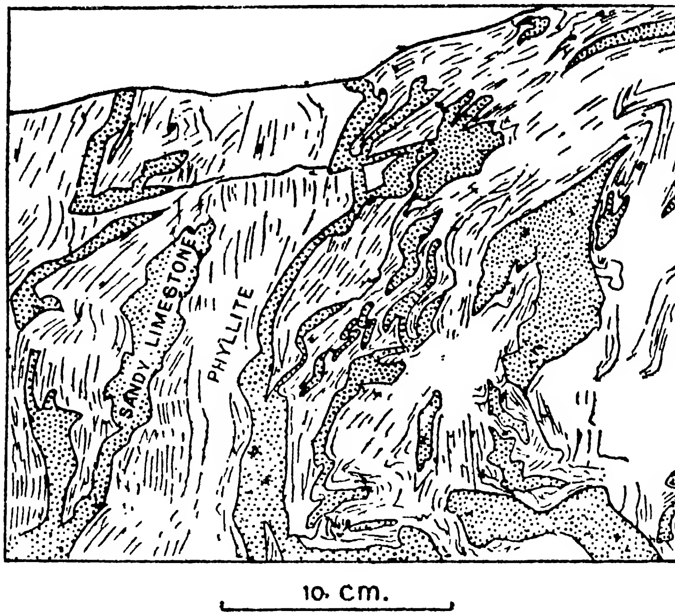



FIG. 6.—Twisted lenticles of sandy limestone in phyllite, Mandhali beds, 0·6 miles north of Sataun, Giri river.

comparison with those of the Krol A stage (Fig. 7) is due to the fact that the argillaceous phase in the Mandhalis was already a clay-slate or phyllite at the time of the folding, and therefore reacted in a more rigid manner.

## Age of Thrusting.

In the Kalsi area, the Krol thrust brings pre-Tertiary rocks to rest upon Nahans. The thrust must therefore be of Miocene or later age.

At Bilaspur, Krol limestones are seen to rest at 30°–40° upon Upper Siwalik conglomerates. The latest movement of the thrust here cannot be older than Pliocene.[1] The same inference applies

[1] This thrust has not been joined up with the Krol thrust of the area included in the map.

to the thrust at Dhaduwala, south of Nahan, which brings Middle Siwaliks to rest upon Upper Siwaliks.

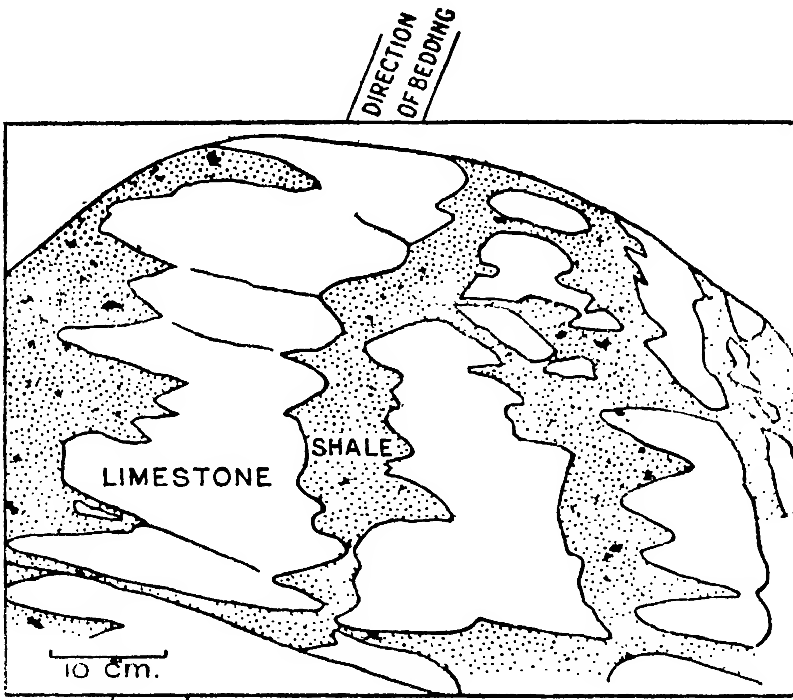



FIG. 7.—Yield of impure limestone, by flow, in calcareous shale, Krol A stage, a quarter of a mile W. S. W. of height 3,278 feet, Nera (Newali) *nala*. Compare with Plate 22 in which deformation is less.

In contrast to this dating, Middlemiss[1] found that the Upper Siwalik conglomerates have overlapped the Nahans, on to the traps of the pre-Tertiary rocks, truncating the Main Boundary fault. This proves that the Main Boundary fault of Garhwal was pre-Pliocene. Middlemiss also notes that a later reversed fault, in the same Gangolia locality, has brought Middle Siwaliks on to Upper Siwaliks. The thrusting must, therefore, have continued over a considerable length of time.

Morphology.

A difficulty is raised by the late age of some of these thrusts. By Pliocene times, the main drainage system of the Himalaya is believed to have been well established. The late Pliocene thrusts must, therefore, have act-

[1] *Mem. Geol. Surv. Ind.*, XXIV, p. 107, (1890).

ed on a region already largely dissected into separate orographical areas. To what extent these areas, with intervening river valleys, limited the nature of the tectonic structures present in them, will be very difficult to decide. Once a river has carved down several thousands of feet, it may be presumed that pressures above the level of the river must have been confined to the orographical units in which they occurred, and must have been relieved by structures peculiar to those units. The Krol thrust certainly crosses the Tons and Jumna rivers undeflected, so that the whole of the Krol Belt must have moved forward as a tectonic unit before the rivers had cut down to their present levels and had divided up the country into the modern orographical areas.

Ampferer has described *relief-overthrusting* in the Alps, by which translation of rock masses has taken place over a topography previously determined by subaerial erosion.[1] The whole question of morphology in relation to tectonic history is, however, too difficult to discuss here.

## Inclination of Thrusts.

The inclination of both the Krol and Giri thrusts is found to be very variable, in some places being only 20°, in others inverted. Mr. P. Lake[2] has deduced that the thrust-plane at the base of the Himalaya must have a dip, at its outcrop, of 14°. He suggested in 1903 that the visible boundary faults of the Himalaya are probably minor thrusts, since the actual base of a modern mountain chain would be obscured by the products of its own denudation (Siwaliks and modern Ganges alluvium). Dr. Fermor[3] has drawn attention to a paper by Mr. Middlemiss[4], in which the inclination of the thrust at Kotli between the Murrees (Dagshais) and the underlying Middle and Upper Siwaliks, is actually 12° to 15°. This thrust was taken by Dr. Fermor to be the Main Boundary fault, and Mr. Lake has accordingly allowed that the real basal thrust-plane of the Himalaya does in fact crop out, and at an inclination

[1] *Jahrb. geol. Bundesanst. Wien*, LXXVIII, p. 241, (1928).

[2] *Geol. Mag.*, p. 305, (1903); *op. cit.*, p. 34, (1931). *Geog. Journ.*, LXXVIII, No. 2, p. 151, (1931).

[3] *Rec. Geol. Surv. Ind.*, LXII, p. 410, (1929)

[4] *Op. cit.*, L, p. 122, (1919).

that agrees with the theoretical value. Mr. Wadia[1] has shown that this thrust cannot be considered a boundary fault. It does not form a limit to the deposition of the Siwalik sediments, and, moreover, it terminates a short distance to the northwest in an anticlinal fold. The point at issue, however, is not the actual nature of the thrust-plane described by Middlemiss, but the variability of inclination of most of the Himalayan thrusts. Mr. Wadia agrees with me in the experience that a thrust may change greatly in dip within a distance of a few miles. The thrusts began, doubtless, with a rapid forward movement, when elastic limit was reached, but they must have slowed down as this original stress was relieved, and as resistance of the underlying and frontal foreland became greater. Cadell's experiments[2] have shown that horizontal pressure applied at one point is not propagated far forward into the mass, and it seems legitimate to suppose that, in proportion as pressures in one part are relieved, so would new pressures and strains arise in the part to which the thrust masses have been translated. It would be expected that increase in frontal resistance would tend to cause the folding of the whole structure of overthrust mass, and overridden mass, as a single unit. The original disposition of the thrusts, that might have better accorded with theoretical inclinations required for movement along plane surfaces, would consequently be obscured.

Further, the rocks undergoing folding and thrusting are not homogeneous, and it would hardly be expected that relief from pressure would take place with mathematical perfection. The resistance offered by the Bohemian *massif* to the advancing Alpine folds may be cited as an example of the kind of deflection that is caused by the local presence of a stiff unit of the foreland.

The coincidence of the theoretical inclination of 14°, deduced by Mr. Lake, with the observed inclination of a part of the Kotli thrust must be fortuitous. It may, moreover, be questioned whether there is a single thrust, of unique importance, to which Mr. Lake's deductions can be applied. It appears to the writer that the conception of a 'Main Boundary fault', and hence of a basal thrust-plane to the Himalaya, has been carried too far. It arose at a time when the faults were thought actually to mark the successive limits of sedimentation against the uprising Himalaya,

[1] *Mem. Geol. Surv. Ind.*, LI, Pt. 2, (1928); map at the end of Memoir.
[2] *Trans. Roy. Soc. Edin.*, p. 337, (1890).

and when the structure of the pre-Tertiary rocks had not been examined in detail. Recent work by Pilgrim, Wadia, West and the writer has shown the number of thrusts that actually exist in these pre-Tertiary rocks. Some of these cannot be considered minor structures, comparable solely with the minor thrusts, as distinct from the major thrusts, of the North-West Highlands. The Chail thrust of Mr. West is of premier importance. In the Himalaya, as in the Alps, it would appear impossible to regard any single dislocation or *nappe* as having borne the whole burden of the advance upon the foreland.

## Pre-Tertiary Structures.

A brief note has already been published[1] in which the existence of structures showing a N. E.–S. W., Aravalli, orientation was discussed.

The observations were scattered over a wider area than that here described. Actually along the Krol Belt, the following structures may be noticed :—

(1) In the Palor Ka Khala, above Siyun; conglomerates in the Jaunsar series have been crushed, so that the pebbles have been elongated to ellipsoids. the major axes of which strike 60°–240°. The elongation is seen on dip surfaces. Along one direction at right-angles to the dip surface, the pebbles appear more or less circular. Dip of conglomerates: 30° to E. N. E.

(2) The Jaunsar phyllites at Shallai are thrown into small-scale folds, the size of mega-ripples, the axes of which vary in strike from 80°–260° to 60°–240°. In addition, there are grooves and striæ, on the bedding planes of these phyllites, which strike 35°–215°. These resemble glacial striæ, but are found on close inspection to be minute cross-folds running in the direction of dip of the false cleavage. They appear to resemble the grooves described by Dr. Fermor[2], except that they have no connection with the pitch of the synclinal fold in which they occur. Dip of phyllites and quartzites: 30° to S. S. W.

(3) The Blaini boulder bed on the ridge between Juin and Chandpur summits, has been made schistose. The direction of elongation of the pebbles varies from N. E.–S. W. to E. N. E.–W. S. W. Dip of boulder beds: due west.

(4) The schistosity of the Jaunsar quartz-schists, in the Shamanah ka Khala, below Andra, strikes 45°–225°, the shear-cleavage dip being 70° towards 315°. Dip of quartzites: 65° to S. S. W.

[1] *Rec. Geol. Surv. Ind.*, LXVI, p. 467, (1933).
[2] *Econ. Geol.*, XIX, p. 560, (1924).

These directions are at right angles to the strike now shown by the Himalayan range. They suggest that pressures had formerly acted in approximately a N. W.–S. E. direction, which is the same direction as that of the pressures responsible for the formation of the Aravalli range and its subsequent rejuvenation.

If the Aravalli range be produced across the Gangetic alluvium, it meets the present Himalaya in the region between Chakrata and Naini Tal. It seems a legitimate assumption to regard those structures of N. S.–S. W. orientation in the present Himalaya as having been caused by activity along the Aravalli axis. Such structures have never been noticed in the Infra-Krol and higher series, so it may be assumed that the activity responsible for them ceased in Blaini times, that is, during the Upper Carboniferous.

It has already been stated on page 400 that the folding which was responsible for the unconformity of Blaini upon Jaunsar rocks probably did not have an Aravalli direction. There is therefore a certain degree of anomaly, since the Blaini of the Juin-Chandpur ridge appears to show this Aravalli orientation. Further, no unconformity of orogenic violence is seen between the Blaini and the underlying Jaunsar and Simla series.

The two sets of facts must be left together and unexplained. The commonness of N. E.–S. W. structures in the Himalaya cannot be disregarded. Moreover, they cannot be explained by supposing that their formation was due to strongly rotational Tertiary stresses, since the post-Blaini rocks all show a true Himalayan, N. W.–S. E., orientation of structure.

Besides the structures that I have myself recorded from Garhwal, Middlemiss [1] mentions the prevalence in the Kumaon of folding and cleavage of pre-Tertiary rocks in a north-south direction, which he attributes to an east-west pressure.

It may be maintained with safety that the modern Himalaya contain relics of structures that were due to earlier, non-Himalayan, tectonics.

## XII. ECONOMIC.

The country is very poor in minerals.

It should be remarked that in no instance has any mineral been seen to occur in sufficient quantity to justify exploitation.

[1] *Mem. Geol. Surv. Ind.*, XXIV, p. 125, (1890).

## Barytes.

Barytes occurs, or may have occurred, in the following localities. In all cases it is found in the older rocks.

(1) A discontinuous vein of barytes occurs in the Simla slates near hill 3901 (30° 58′ 30″ : 77° 1′ 15″), two miles E. S. E. of Subathu, on the border of Bharauli and Baghat State. It is about four feet thick and occurs along a fault-plane. It can be traced sporadically for about a mile to the south-east. The barytes contains galena, but in very small amount. The old workings are now almost overgrown with vegetation.

(2) Dr. A. L. Coulson has drawn my attention to references concerning old lead-mines in the same neighbourhood, and I have drawn verbatim from the information he has collected.

'Kelly[1] and Henwood[2] have described mines not far from this neighbourhood, but they have made no mention of barytes.[3] Ball[4], however, gives three localities where ores of lead are said to occur. It is thought that the first of these, namely, "2½ to 3 miles south-east of Huriapur" is the locality mentioned by Mr. Auden.[5] "Huriapur" is probably the village "Haripur" (31° 01′ : 76° 59′) on sheet 53 A/16. Ball adds :—

> "traces of lead ores with barytes are said to occur to the east of the suspension bridge, as far as the Sairan dak bungalow, on the Simla road, but (that) they do not occur to the west."

Sairan is probably Sair (53 E 4, 31° 05′ : 77° 03′), on the track from Subathu to Simla.'

(3) An old working is seen in a *nala* which joins the Kawal Khal at 30° 50′ 30″ : 77° 10′ 20″, Patiala State. It is in Simla slates. No trace of ore was seen and the villagers have no recollection of what was obtained.

(4) In the Jagar ka Khala, Sirmur State (30° 37′ 30″ : 77° 28′), small veins of barytes are found in the Blaini boulder bed. The barytes is much mixed up with shale and effervesces with acid. Specific gravity, 3·94. No galena was seen.

## Gypsum.

Gypsum is found in the Krol limestones in the following localities :—

(1) Near Bhaunrari, Sirmur State (30° 47′ : 77° 14′). Small pockets of gypsum occur in Krol D limestone. These are probably replacement pockets.

[1] *Min. Journ.*, pp. 59-60, (1869).
[2] *Op. cit.*, pp. 67, 471.
[3] *Cf.* La Touche, Bibliography, Pt. 1B, p. 19.
[4] *Econ. Geol.*, p. 305, (1881).
[5] *Rec. Geol. Surv. Ind.*, LXII, p. 31, (1930).

(2) Ridana, Sirmur State (30° 33′ 22″: 77° 44′ 51″). A lenticular bed of gypsum, 20 yards long and a maximum of 18 inches in thickness occurs in Krol A limestone. The specific gravity of some of the material gave the value 2·705, so that there is probably an admixture of gypsum and anhydrite. The greater part of the mineral is gypsum, with specific gravity of 2·306. The deposit appears to be an original one, and not due to replacement.

## Seepages.

In 1928, the Maharaja Sahib of Baghat State asked me to examine some reputed occurrences of iron, near Harat. The material is ferric hydroxide, and occurs as seepages from the Infra-Krol slates. Such seepages are found all along the outcrop of the Infra-Krols, but do not indicate anything of economic interest. White salty efflorescences often occur on the black Infra-Krol slates. Analysis shows them to contain the following radicles:—Cl, $SO_3$, K, Mg, Ca, and Fe.

## XIII. LIST OF PLATES.

## XIV. LOCALITY INDEX.

| | Latitude. | | Longitude. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| Juin Hill, 8,493 feet | 30 | 42 | 77 | 36 |
| Kadhar | 30 | 57 | 77 | 06 |
| Kalka | 30 | 50 | 76 | 57 |
| Kalsi | 30 | 32 | 77 | 51 |
| Kamli Dhar | 30 | 37 | 77 | 31 |
| Kandaghat | 30 | 58 | 77 | 06 |
| Kando | 30 | 38 | 77 | 27 |
| Kandon | 30 | 33 | 77 | 30 |
| Kasauli | 30 | 54 | 76 | 58 |
| Katiara | 30 | 58 | 77 | 03 |
| Khadayat | 30 | 39 | 77 | 41 |
| Khanog Hill, 6,517 feet | 30 | 53 | 77 | 07 |
| Khur | 30 | 39 | 77 | 30 |
| Korgai | 30 | 33 | 77 | 41 |
| Kotla | 30 | 39 | 77 | 23 |
| Krol Hill, 7,393 feet | 30 | 57 | 77 | 06 |
| Koti Dhaman | 30 | 38 | 77 | 33 |
| Kyari | 30 | 43 | 77 | 41 |
| Lakhwar | 30 | 32 | 77 | 58 |
| Lagasan | 30 | 54 | 77 | 09 |
| Lansdowne | 29 | 50 | 78 | 41 |
| Mangal | 30 | 41 | 77 | 38 |
| Mangarh | 30 | 45 | 77 | 15 |
| Manogi | 30 | 35 | 78 | 02 |
| Mareog | 30 | 53 | 77 | 13 |
| Masria | 30 | 51 | 77 | 11 |
| Milan | 30 | 41 | 77 | 23 |
| Milla | 30 | 40 | 77 | 38 |
| Minal Bag | 30 | 37 | 77 | 43 |
| Mishwa | 30 | 37 | 77 | 38 |
| Morar | 30 | 40 | 77 | 46 |
| Naga Tibba | 30 | 36 | 77 | 50 |
| Nagthat | 30 | 34 | 77 | 58 |
| Narag | 30 | 49 | 77 | 11 |
| Narail | 30 | 43 | 77 | 20 |
| Naraya | 30 | 40 | 77 | 50 |
| Niwar | 30 | 48 | 77 | 17 |
| Pathna | 30 | 33 | 77 | 47 |
| Rajana | 30 | 40 | 77 | 27 |
| Rajgarh Hill, 6,941 feet | 30 | 53 | 77 | 10 |
| Rerli | 30 | 41 | 77 | 25 |
| Sainbar Hill, 6,714 feet | 30 | 46 | 77 | 15 |
| Sahiya | 30 | 37 | 77 | 53 |
| Salogra | 30 | 56 | 77 | 08 |
| Sataun | 30 | 33 | 77 | 38 |

| | Latitude. | | Longitude. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| Senj | 30 | 59 | 77 | 08 |
| Shali peak | 31 | 12 | 77 | 17 |
| Shallai | 30 | 40 | 77 | 42 |
| Shalamun | 30 | 52 | 77 | 14 |
| Shiwa Kalan | 30 | 34 | 77 | 45 |
| Siyun | 30 | 42 | 77 | 22 |
| Soat Hill | 30 | 41 | 77 | 26 |
| Solon | 30 | 55 | 77 | 07 |
| Subathu | 30 | 58 | 76 | 59 |
| Sunny (Sunnu) | 30 | 56 | 77 | 10 |
| Tikar | 30 | 42 | 77 | 30 |
| Tikari | 30 | 39 | 77 | 25 |
| Udpalta | | | | |

*Heights.*

| | | | | |
|---|---|---|---|---|
| 1,808 feet | 30 | 32 | 77 | 54 |
| 2,206 feet | 30 | 44 | 77 | 43 |
| 2,820 feet | 30 | 50 | 77 | 15 |
| 3,241 feet | 30 | 50 | 77 | 10 |
| 3,278 feet | 30 | 39 | 77 | 38 |
| 3,619 feet | 30 | 36 | 77 | 28 |
| 4,217 feet | 30 | 34 | 77 | 29 |
| 4,633 feet | 30 | 51 | 77 | 08 |
| 4,819 feet | 30 | 57 | 77 | 02 |
| 4,960 feet | 30 | 58 | 77 | 03 |
| 6,458 feet | 30 | 34 | 77 | 43 |
| 6,474 feet | 31 | 00 | 77 | 06 |
| 6,925 feet | 30 | 40 | 77 | 54 |
| 7,005 feet | 30 | 40 | 77 | 29 |
| 7,216 feet | 30 | 40 | 77 | 30 |

# ON SOME CRUSH CONGLOMERATES OF DHARWAR AGE FROM CHOTA NAGPUR AND JUBBULPORE.[1] BY M. S. KRISHNAN, M.A. (MADRAS), PH.D. (LONDON), A.R.C.S., D.I.C., *Assistant Superintendent, Geological Survey of India.* (With Plates 26-29.)

## INTRODUCTION.

In this paper are described some crush conglomerates occurring in the Gangpur State of Bihar and Orissa and in the Jubbulpore district of the Central Provinces. In both cases they form part of the Dharwar sequence. Conglomerates from other parts of India and from similar formations have been described, except in a few cases, as of autoclastic origin. It is the aim of the writer to show that those dealt with here are of sedimentary origin, though locally, the crushing and shearing have been so intense as to obliterate the original nature and impose autoclastic characters.

## OCCURRENCE AND GEOLOGICAL RELATIONSHIP.

In Gangpur State a very conspicuous zone of conglomerate occurs at the top of a sequence of Dharwar rocks consisting of mica-schists, phyllites, manganiferous rocks of the gondite type, dolomitic and calcitic marbles, and carbonaceous phyllites and quartzites. This zone forms the southern border of the Gangpur anticlinorium and stretches almost continuously from near Jaraikela (22° 18′ : 85° 7′) to Bamra (22° 3′ : 84° 17′), one to three miles north of the Bengal-Nagpur Railway track connecting the above two stations. Some outlying outcrops belonging to the same zone occur near Kolpotka (22° 22′ : 85° 6′) on the east, and at Bijadih (22° 4′ : 84° 15′) and Amasranga (22° 1′ : 84° 11′) on the west. This has a general E.-W. strike which varies at either end to E. N. E.-W. S. W., and a dip of 75° to 90° towards the south.

[1] Paper read before the Geology Section of the Twentieth Session of the Indian Science Congress, Patna, (1933).

In this region other conglomerate zones occur in association with masses of quartzite forming the Gamburu-Durgapata ridge in the south-eastern corner of sheet of 73 B/S. E., and in the Bhaisamunda *pahar* (22° 2′ : 84° 46′), a few miles to the west of the former. These are believed to be members of the Iron-ore series. The dip is fairly steep towards the north and the strike the same as that of the first zone, *i.e.*, nearly E.–W.

In the Jubbulpore district of the Central Provinces, conglomerates occur in the area to the east and E. S. E. of Sleemanabad (23° 38′ : 80° 15′). The main formations here are dolomitic marbles and mica-schists in which a few bands of conglomerate are found. These bands vary in thickness from a few feet to about a hundred feet. The two thickest ones are situated one mile south of Bhitrigarh (23° 37′ : 80° 25′) and a quarter of a mile north of Ghunsa (23° 35′ : 80° 21′), respectively. Other thinner beds are found near Mehgawan (23° 39′ : 80° 22′), Durghati Piparia (23° 38′ : 80° 24′), Bhadanpur (23° 34′ : 80° 22′) and Sahdar (23° 34′ : 80° 23′).

The formations in the Jubbulpore area were originally considered as belonging to the Bijawars[1] by C. A. Hacket, but subsequent examination by Dr. L. L. Fermor led to their inclusion in the Dharwars.[2] In addition to their approximate identity in age, there is a great deal of similarity in the lithology of the rocks in Jubbulpore and Gangpur. But, as is common with rocks of Pre-Cambrian age occurring in widely separated areas, a direct correlation connot be made with any degree of certainty.

## Description of the Conglomerates.

The general mass of rock in the main band in the Gangpur area is a medium-grained, micaceous quartz-schist with quartz and subordinate muscovite as the chief constituents. When followed along the strike, the conglomerate bed shows some variation in thickness and sometimes grades into gritty schists. The typical rock shows a number of flattened pebbles in a mass consisting of fine-grained, highly quartzose, micaceous schist. The boundaries of the pebbles are generally clean and marked by films of muscovite. The pebbles are flat ellipsoidal in shape, the flat faces lying on the shear-plane and sometimes showing slickensides.

[1] Hacket's manuscript reports for the seasons 1869-70 and 1870-71.
[2] *Mem. Geol. Surv. Ind.*, XXXVII, p. 805, (1909).

### *Type A.*

Specimens belonging to this type are best termed gritty quartz-schists containing no pebbles of comparatively large size. They form a transition between quartz-schists on the one hand and conglomerates on the other. They show a schistose structure (Plate 28, fig. 1) and medium to coarse texture. A small quantity of muscovite is interspersed among the grains, and sometimes films of this mineral show slickensides as evidence of shear (*e.g.*, specimens 38·59, 38·147, 38·156,[1] etc.).

Under the microscope the quartz grains are seen to be of various sizes, with a distinct tendency to parallelism of arrangement. Some are quite rounded, while others are sub-angular or angular. The larger grains are surrounded by finer ones and all generally show undulatory extinction.

### *Type B 1.*

Under this type are included conglomerates and crush breccias of the Gangpur region. All of them are predominantly quartz-conglomerates, the pebbles being made up of quartzite, micaceous quartz-schist, translucent vitreous quartz and fine-grained biotite-schist in the order of diminishing abundance. Occasionally, tourmaline-quartz-rock is also found as pebbles (40·86).

The type illustrated by specimen 43·207, which was collected from the foot of the hill on the Singhbhum-Gangpur boundary near Baliam (22° 8′ : 85° 1′), is properly called a crush breccia. It is variegated in appearance, the groundmass being dark greenish grey and the pebbles white to grey. The groundmass contains chlorite, sericitic matter, some biotite and magnetite (Plate 28, fig. 2). The pebbles are of translucent quartz, white to pinkish quartzite and banded blue-grey quartzite. Specimen 37·949, from the hill one mile north of Bisra (22° 15′ : 85° 0′), resembles the above but is somewhat more sheared. The groundmass contains a little tourmaline in addition to the minerals seen in the other specimen. Another specimen (44·170) collected from near Kusumdih (22° 1′ : 84° 46′) is rather less crushed than the two mentioned above.

### *Type B 2.*

Under this may be included all the other occurrences of conglomerate in the Gangpur region, as practically all of them show

[1] Numbers such as 38·59 refer to the registered specimens in the rock collections of the Geological Survey of India.

the effect of intense shear. Specimens broken across the schistosity reveal long, lenticular, inter-digitating pebbles, cemented by quartzose and micaceous material. The pebbles are of saccharoidal quartzite, muscovitic quartz-schist, biotite-quartz-schist and occasionally even phyllite (37·948; Plate 28, fig. 3). Occasional pebbles of granite (Plate 28, fig. 4) were noted in the exposures near Kolpotka (37·888 and 37·889), and of tourmaline-quartz-rock in the Mahabir *pahar* (22° 8′ : 84° 21′). In a few cases, there is little or no difference between the nature of some of the pebbles and that of the groundmass [ 40·94 from near Salebira (22° 6′ : 84° 13′), and 40·150 from the ridge just to the north of Bhaisamunda *pahar* ], so that these pebbles are undoubtedly of autoclastic origin.

In the Jubbulpore area, the occurrences can conveniently be classified into three types of conglomerate and one of breccia.

### *Type C 1.*

The ridges near Bhitrigarh, Ghunsa and Durghati Piparia all consist of conglomerates containing large pebbles of quartzite, which sometimes attain to a length of about twelve inches. The average size is, however, between three and six inches. Specimen 44·41 (Plate 26, fig. 1) is a good example of this, collected from a quarry near Durghati Piparia. The pebbles in this are well rounded, apparently by the action of water. Their surfaces are generally smooth and clean. The groundmass is composed of fine-grained quartz with a little sericite and ferruginous matter and occasional small cubes of pyrite. Compared with the others, this type seems to have undergone the least amount of crushing.

### *Type C 2.*

This is found in some of the smaller ridges, and particularly the one near Mehgawan (specimens 44·42, 44·48, 44·49). The effect of crushing is evident in the broken-up sub-angular pebbles (Plate 26, fig. 2), some of which have been recemented after a little differential movement. Secondary veinlets of quartz can be seen to run through the groundmass and pebbles uninterruptedly. Under the microscope (thin sections 21933, 21937[1]), the larger grains

[1] Numbers such as 21933, etc., refer to the registered number of the thin section in the collections of the Geological Survey of India.

of quartz are seen surrounded by finely granulated material (Plate 29, fig. 1), which consists of quartz, chlorite, sericite and ferruginous matter. The pebbles are of quartzite and chalcedonic quartz or chert. It is interesting to note that the latter, on weathering, become opaque and granular and indistinguishable from quartzite.

### *Type C 3.*

The band occurring near Sahdar, which is about twenty feet thick, shows sub-angular pebbles of quartz and banded hæmatite-quartzite (Plate 27, fig. 1, specimen 44·44). The rock is grey in colour. Under the microscope (thin section 21935, Plate 29, fig. 2) the banded structure of the pebbles is well seen. The iron-ore is bright steel-grey in reflected light, granular in texture with a fairly marked tendency to develop crystal outlines. It is not magnetite since it is not attracted by a magnet. The quartz of these pebbles is fine-grained and granular and varies somewhat in size in different bands.

### *Type D.*

This type, represented by specimen 44·39 (Plate 27, fig. 2), is a breccia forming the main mass of the ridge situated about a third of a mile north of the original site of Amehta village (23° 39′ : 80° 23′). A rest house of the Irrigation Department has recently been built on this ridge. The rock is composed of white quartz, which cements the broken fragments and wisps of a dark blue-grey quartz of an earlier age. The colour of the latter is seen under the microscope to be due to dusty black inclusions (section 21930).

The dark quartz seems to have been first brecciated, and into this the white quartz injected at a later date. The latter, which is of the nature of vein-quartz, has been injected more than once, as earlier veins are often seen to be intersected by later ones.

## OTHER ANCIENT CONGLOMERATES IN INDIA.

A large number of occurrences of conglomerates has been recorded from rocks of similar age in different parts of India, a fairly

large proportion of which being from Mysore. The majority, including the all the Mysore occurrences, have been assigned to the autoclastic group.

Bruce Foote[1] has described several conglomerates and boulder beds in the Lower Transitions of the Bellary district, Madras. They have all been regarded by him, presumably, as sedimentary. Dr. L. L. Fermor[2] has observed a conglomeratic grit underlying the manganese-ore band at Ukua and Balaghat in the Central Provinces. It is regarded as a metamorphosed conglomeratic grit, containing pebbles of white quartz, granite and gneiss set in a matrix which resembles mica-gneiss in general composition. Mr. J. M. Maclaren[3], working in the Tungabhadra region in Southern India, came across some boulder beds and conglomerates in which the pebbles and boulders of granite, aplite, quartz-porphyry, quartzite and banded jasperoid quartz are found embedded in a schistose felspathic matrix with some chloritic matter. These have been classified by him under sedimentary rocks. Some conglomerates of the Aravalli system, described by Dr. A. M. Heron[4], and considered by him as of sedimentary origin, occur at Rewasa in Rajputana and contain pebbles of white quartz, pale and dark grey quartzite, white grit and mica-schist, in a matrix of biotite and chlorite and euhedral grains of magnetite. The pebbles are flattened along the foliation planes. Dr. J. A. Dunn[5] has recently ascribed a sedimentary origin to sheared conglomerates, similar to the Gangpur ones, occurring in North Singhbhum. He considers them to have been deposited during periods of inter-volcanic erosion.

According to Sir Henry Hayden[6], the Lower Haimantas in the valley of the Lipak river show a crush conglomerate. The quartz pebbles found in a matrix of biotite-schist are believed by him to represent portions of veins which have been broken up by intense crushing. A basic dyke in the neighbourhood is also said to have been similarly converted into strings of pebbles. These occurrences have, therefore, been regarded as truly autoclastic.

Several occurrences of conglomerate have been reported from Mysore. Those which were examined prior to about 1908 were

[1] *Mem. Geol. Surv. Ind.*, XXV, pp. 80, 87, 105-107, 140, (1895).
[2] *Op. cit.*, XXXVII, Pt. 2, p. 311, (1909).
[3] *Rec. Geol. Surv. Ind.*, XXXIV, p. 108, (1906).
[4] *Mem. Geol. Surv. Ind.*, XLV, Pt. 1, pp. 17, 22, (1917).
[5] *Op. cit.*, LIV, pp. 32-35, (1929).
[6] *Op. cit*, XXXVI, Pt. 1, pp. 11-12, (1912).

described as sedimentary, but since then, under Dr. W. F. Smeeth's inspiration, all of them have been one by one transferred to the autoclastic group. Those found later have all been described as autoclastic. Mr. C. S. Middlemiss[1] has remarked on the vigour and unanimity with which the autoclastic origin has been advocated and adopted, and on the unacceptability of these conclusions at least in their entirety. He has also pointed out that Dr. Smeeth himself was apparently getting rather tired of the 'hornet's nest' of autoclastic conglomerates which he had raised.[2] Among these, particular mention may be made of the Kaldurga conglomerate. Bruce Foote[3] thought that they were clastic. Mr. H. K. Slater[4] left their origin as doubtful, but Dr. Smeeth[5] gave a decisive opinion, favouring the autoclastic origin, which was later confirmed by Mr. P. Sampat Iyengar[6] as the result of a very detailed study. In his annual report for the year 1909-10, Dr. Smeeth[7] describes briefly the Mallapanhalli, the Gudad-Rangavanhalli (G. R.) formation, the Aimangala and the Kolar conglomerates, to all of which he assigns an autoclastic origin. Other rocks of the same nature have been studied by Messrs. H. K. Slater[8], P. Sampat Iyengar[9], B. Jayaram[10], A. M. Sen[11], and B. Balaji Rao[12] in different parts of Mysore.

## DISCUSSION AND CONCLUSION.

The criteria for distinguishing autoclastic from crush conglomerates of sedimentary origin are generally difficult of application in the field where highly folded and metamorphosed sediments are concerned. Crush conglomerates generally occur at the junction of dissimilar rocks—dissimilar particularly in their physical characters, such as hardness and plasticity under stress. The harder rock is broken up into fragments, while the softer is milled and

[1] Presidential address to the Geology Section, Fourth Indian Science Congress, Bangalore. *Proc. As. Soc. Bengal,* N. S. XIII, p. cxcvi, (1917).
[2] *Rec. Mys. Geol. Dept.,* XII, p. 38, (1912).
[3] *Rec. Geol. Surv. Ind.,* XV, p. 195, (1882).
[4] *Rec. Mys. Geol. Dept.,* VII, Pt. 2, pp. 1-4, (1906).
[5] *Op. cit.,* XIV, p. 25, (1915).
[6] *Op. cit.,* XV, Pt. 2, pp. 107-116, (1916).
[7] *Op. cit.,* XI, pp. 1-67, (1910).
[8] *Op. cit.,* XII, Pt. 2, 26-29, (1912).
[9] *Op. cit.,* XII, Pt. 2, pp. 54-55, (1912).
[10] *Op. cit.,* XIV, pp. 93-94, (1915).
[11] *Op. cit.,* XIV, pp. 150-152, (1915).
[12] *Op. cit.,* XXV, p. 88, (1926).

foliated and forms the matrix in which the fragments of the former get lodged. Under the intense crushing and shearing to which the ancient rocks have generally been subjected, the original depositional structures, if present, would obviously have been more or less obliterated. If the pebbles can be proved to have been contributed by rocks of later age than the matrix in which they are found, the rock must evidently be a pseudo-conglomerate. The presence of igneous rocks of an age later than that of the matrix is useful in this connection, particularly if uncrushed bands of these lie contiguously with the crushed portion. This is exemplified in the case of the Spiti and the Kaldurga rocks which have been referred to above.

In the conglomerates dealt with in the present paper, the Durghati Piparia rock (C 1) seems to the writer to be an undoubted sedimentary conglomerate. Among the occurrences described, this shows the least amount of crushing. At other places along the same band, more crushed portions can be seen. The occurrence at Sahdar (C 3) shows semi-angular pebbles of iron-ore-quartzite. There are no rocks of this nature in the immediate neighbourhood. It seems reasonable to think that the fragments have been transported by water from their original source, wherever it might have been. Leaving aside type D, which is of the nature of an igneous breccia, the other rocks in the Jubbulpore area show progressive stages in crushing.

In the Gangpur area, the pebbles of the conglomerate are found to be of varied nature—biotite-schist, quartzite, tourmaline-quartz-rock, and rarely granite. In the field, the conglomerates have the appearance of those due to epiclastic origin. No example has been found in which an uncrushed vein or band passes into a string of pebbles in the conglomerate. In a few cases, however, as in the minor lenticular bands amidst the quartzites of the Gamburu-Durgapata ridge, the conglomerates may be autoclastic, as the pebbles in some cases are seen to be identical in composition with the matrix.

From this study it is concluded that practically all the cases represent conglomerates of original sedimentary origin. In places, the sedimentary characters have been obscured by intense crushing and shearing. The breccia at Amehta is of a special type, while a few minor occurrences in the south-east of Gangpur seem to be autoclastic.

## EXPLANATION OF PLATES.

PLATE 26, FIG. 1.—Conglomerate with large rounded pebbles, Durghati Piparia, Jubbulpore. Specimen 44·41. Negative 4370.

FIG. 2.—Conglomerate with sub-angular pebbles, Bhitrigarh, Jubbulpore. Specimen 44·42. Negative 4372.

PLATE 27, FIG. 1.—Conglomerate with pebbles of dark, banded iron-ore–quartzite, Sahdar, Jubbulpore. Specimen 44·44. Negative 4373.

FIG. 2.—Brecciated dark quartzite cemented by white quartz, ridge near Amehta, Jubbulpore. Specimen 44·39. Negative 4371.

PLATE 28, FIG. 1.—Schistose conglomerate. Parallelism of muscovite flakes. Crossed nicols. × 25. Section 19995. Negative 1787.

FIG. 2.—Showing coarser quartz surrounded by finer granulated quartz. Crossed nicols. × 25. Section 21389. Negative 1790.

FIG. 3.—Showing patches of phyllite. Crossed nicols. ×25. Section 19838. Negative 1785.

FIG. 4.—Showing patches of phyllite and a granite pebble with plagioclase. Crossed nicols. ×25. Section 19902. Negative 1786.

PLATE 29, FIG. 1.—Coarse pebble with a vein of quartz surrounded by finely granulated quartz. Crossed nicols. ×25. Section 21933. Negative 1782.

FIG. 2.—Showing pebble of banded iron-ore–quartzite. Crossed nicols. ×25. Section 21935. Negative 1784.

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## T

*J. B Auden, Photo* *G. S. I., Calcutta*

KAMLI DHAR AND GIRI RIVER, FROM NEAR CHANDNI (HEIGHT DIFFERENCE 4,750 FEET). MANDHALI, JAUNSAR AND KROL SERIES.

J. B Auden, Photo. G. S. I., Calcutta

GUMA PEAK, 8,098 FEET, FROM NIGALI DHAR. SYNCLINE OF UPPER TAL QUARTZITES AND SHALES, WITH VERTICAL NORTHERN LIMB. KROL LIMESTONES ON GUMA.

*J B. Auden, Photo.* *G. S. I., Calcutta*

OVERFOLD IN KROL D STAGE. VIEW OF MANGARH VILLAGE, WITH BHARAN, SAINBAR, AND 6,687 FEET HILLS IN THE DISTANCE.

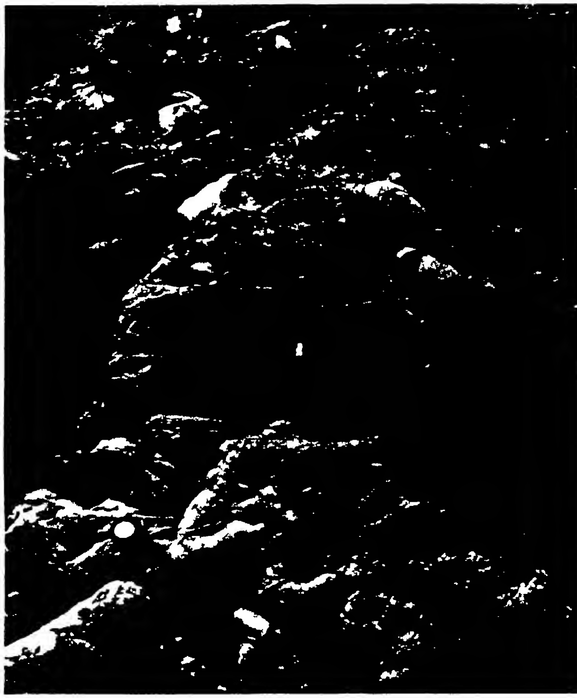
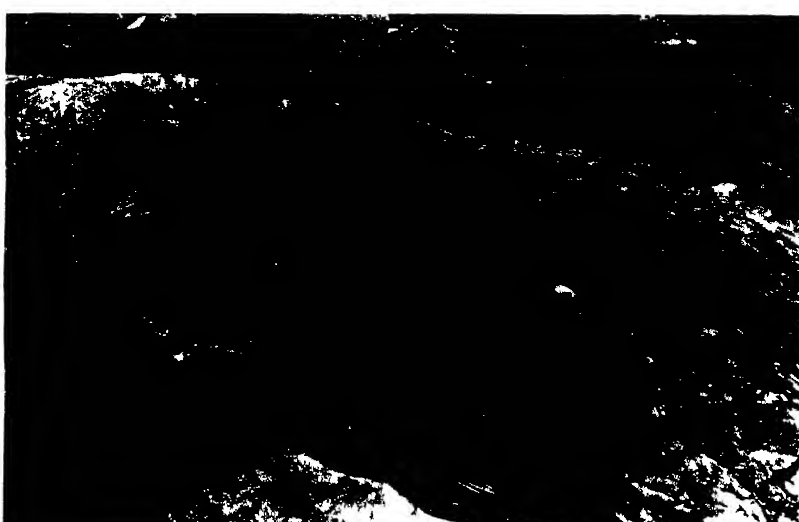
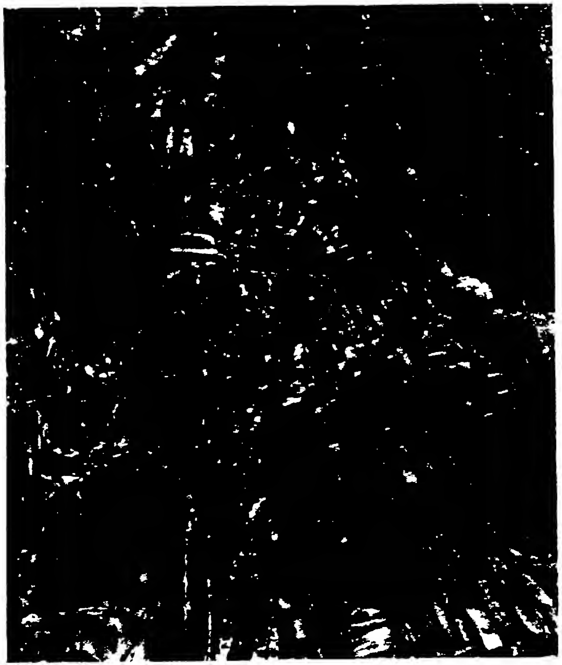


FIG 1 BLAINI BOULDER BED, CONFLUENCE OF BLAINI AND GAMBHAR RIVERS





*J. B Auden, Photos.* *G. S I., Calcutta*

FIG. 1. FAULT ZONE IN KROL A LIMESTONES AND SHALES, GIRI RIVER, THREE-QUARTERS OF A MILE NORTH OF DADAHU.

FIG 2 STEEPLY TILTED RIPPLE-MARKED JAUNSAR QUARTZITES, GIRI RIVER, ONE MILE BELOW NARAIL.

*J. B. Auden, Photo.* *G. S. I., Calcutta*

DEFORMATION OF KROL A LIMESTONE AND SHALE BY FLOW, ONE-QUARTER OF A MILE W. S. W. OF HEIGHT 3,278 FEET, NERA (NEWALI) NALA.

*J. B. Auden, Photo* *G. S I, Calcutta.*

DARK, CURRENT-BEDDED, SANDY LIMESTONE OVERLYING PALE QUARTZITES, UPPER TALS
CURRENT-BEDDING CONCAVE UPWARDS NIGALI DHAR, THREE-QUARTERS
OF A MILE NORTH-EAST OF KOTI DHAMAN

Records, Vol. LXVII, Pl. 26.

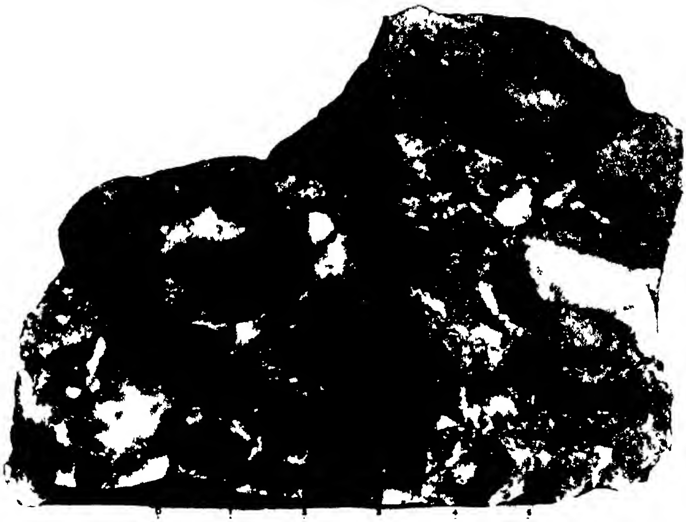


FIG. 1. CONGLOMERATE WITH LARGE ROUNDED PEBBLES, DURGHATI PIPARIA, JUBBULPORE


P L Dutt, Photos.

G. S. I., Calcutta.

FIG. 2. CONGLOMERATE WITH SUB-ANGULAR PEBBLES, BHITRIGARH, JUBBULPORE.

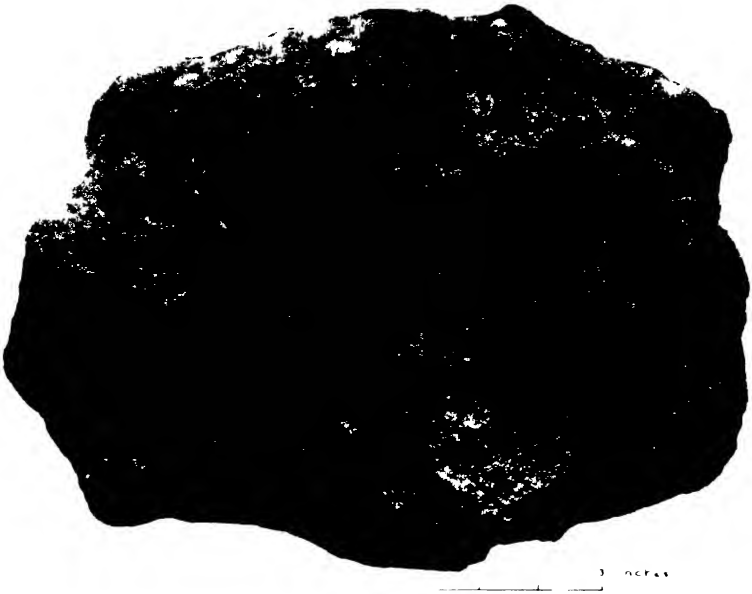
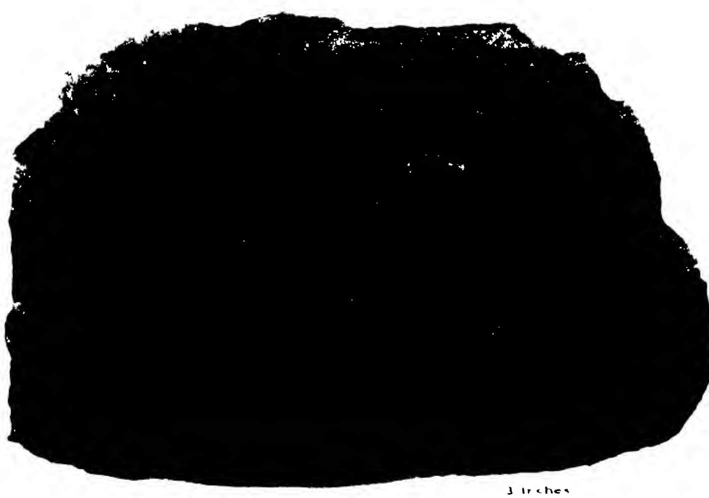


FIG 1 CONGLOMERATE WITH PEBBLES OF DARK, BANDED IRON ORE-QUARTZITE, SAHDAR, JUBBULPORE



*P I Dutt, Photos* *G. S. I., Calcutta*

FIG 2 BRECCIATED DARK QUARTZITE, CEMENTED BY WHITE QUARTZ, RIDGE NEAR AMEHTA, JUBBULPORE.

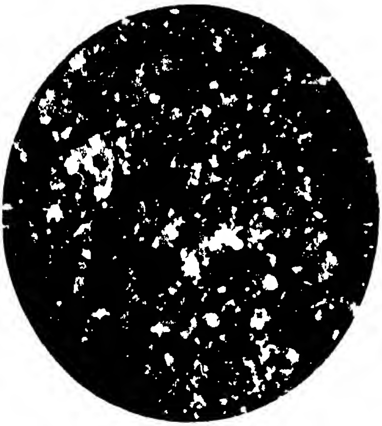


FIG 1 SCHISTOSE CONGLOMERATE SHOWING PARALLELISM AMONG MUSCOVITE FLAKES.
Crossed nicols ( X 21 ).

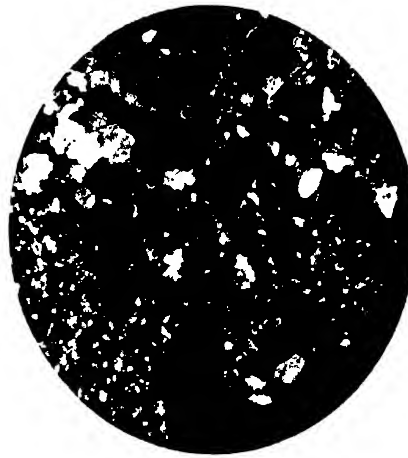
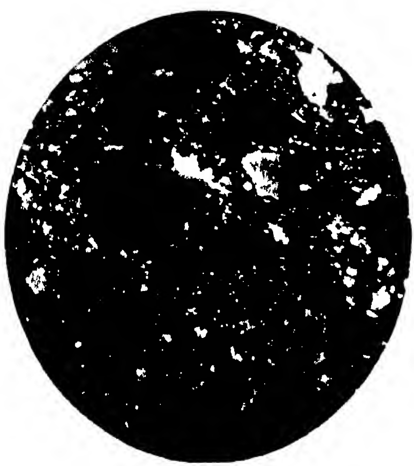
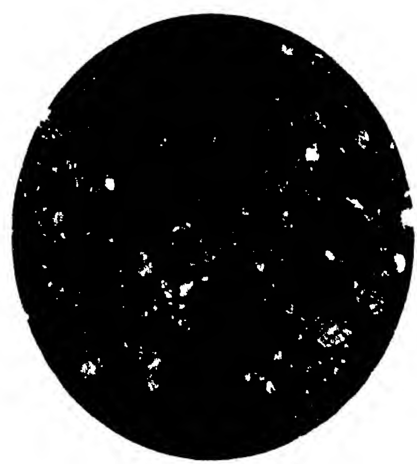


FIG 2. SHOWING COARSER QUARTZ SURROUNDED BY FINER GRANULATED QUARTZ.
Crossed nicols ( X 21 ).





*M. S Krishnan & P L Dutt, Photomicros.*

*G. S. I., Calcutta.*

FIG. 3. SHOWING PATCHES OF PHYLLITE.

Crossed nicols ( X 21 ).

FIG. 4. SHOWING PATCHES OF PHYLLITE AND A PEBBLE OF GRANITE WITH PLAGIOCLASE.
Crossed nicols ( X 21 ).

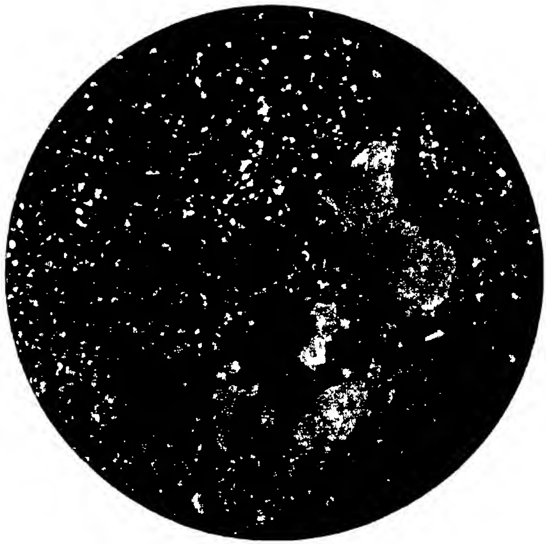
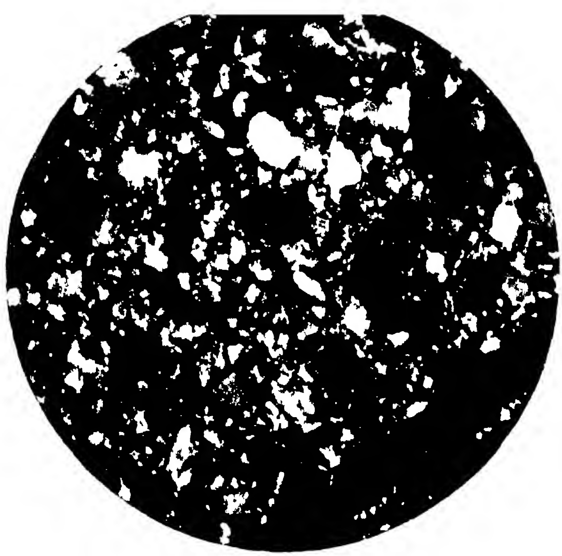


FIG 1 SHOWING A COARSE PEBBLE, VEINS AND FINELY GRANULATED MATRIX, ALL OF QUARTZ.
Crossed nicols ( × 25 ).



*Krishnan & P. L Dutt, Photomicros.* *G. S. I., Calcutta.*

FIG. 2. SHOWING PART OF A DARK, BANDED, IRON-ORE-QUARTZITE PEBBLE.
Crossed nicols ( × 25 ).